Nos. 24-1587, 24-1588

IN THE

United States Court of Appeals

FOR THE FEDERAL CIRCUIT

TQ DELTA, LLC,
Plaintiff-Appellant,

v.

COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE, INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS U.S. HOLDINGS, INC., ARRIS SOLUTIONS, INC., ARRIS TECHNOLOGY, INC., ARRIS ENTERPRISES LLC,
Defendants-Cross-Appellants,

AVAGO TECHNOLOGIES INTERNATIONAL SALES PTE. LIMITED, BROADCOM INCORPORATED, BROADCOM CORPORATION,
Defendants/Third Party Plaintiffs/ Counterclaimants.

On Appeal from the United States District Court
for the Eastern District of Texas
No. 2:21-cv-00310-JRG, Judge J. Rodney Gilstrap

NONCONFIDENTIAL OPENING BRIEF FOR PLAINTIFF-APPELLANT TQ DELTA, LLC

Peter J. McAndrews
Rajendra A. Chiplunkar
David Z. Petty
MCANDREWS, HELD & MALLOY, LTD.
500 West Madison Street, 34th Floor
Chicago, IL 60661
(312) 775-8000
pmcandrews@mcandrews-ip.com

Jeffrey A. Lamken
Rayiner Hashem
Jennifer Elizabeth Fischell
MOLOLAMKEN LLP
The Watergate, Suite 500
600 New Hampshire Avenue, N.W.
Washington, D.C. 20037
(202) 556-2000
jlamken@mololamken.com

Counsel for Plaintiff-Appellant TQ Delta, LLC
(Additional Counsel Listed on Next Page)

Elizabeth Kathleen Clarke
MOLOLAMKEN LLP
300 North LaSalle Street
Chicago, IL 60654
(312) 450-6704

Catherine Martinez
MOLOLAMKEN LLP
430 Park Avenue
New York, NY 10022
(212) 607-8152

Counsel for Plaintiff-Appellant TQ Delta, LLC

PATENT CLAIMS AT ISSUE ON APPEAL

U.S. Patent No. 8,090,008, Claim 14

[pre] A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:

[a] associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;

[b] computing a phase shift for each carrier signal based on the value associated with that carrier signal; and

[c] combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

U.S. Patent No. 8,462,835, Claim 10

The apparatus of claim 8, wherein a first interleaver parameter value of the first FIP setting is different than a second interleaver parameter value of the second FIP setting.

Claim 8 recites:

[pre] An apparatus configurable to adapt forward error correction and interleaver parameter (FIP) settings during steady-state communication or initialization comprising:

[a] a transceiver, including a processor, configurable to:

[b] transmit a signal using a first FIP setting,

[c] transmit a flag signal, and

[d] switch to using for transmission, a second FIP setting following transmission of the flag signal,

wherein:

[e] the first FIP setting comprises at least one first FIP value,

[f] the second FIP setting comprises at least one second FIP value, different than the first FIP value, and

[g] the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

CERTIFICATE OF INTEREST

Case Number 24-1587, 24-1588

Short Case Caption TQ Delta, LLC v. CommScope Holding Company, Inc.

Filing Party/Entity TQ Delta, LLC

Instructions:

1. Complete each section of the form and select none or N/A if appropriate.
2. Please enter only one item per box; attach additional pages as needed, and check the box to indicate such pages are attached.
3. In answering Sections 2 and 3, be specific as to which represented entities the answers apply; lack of specificity may result in non-compliance.
4. Please do not duplicate entries within Section 5.
5. Counsel must file an amended Certificate of Interest within seven days after any information on this form changes. Fed. Cir. R. 47.4(c).

I certify the following information and any attached sheets are accurate and complete to the best of my knowledge.

Date: 07/19/24

Signature: /s/ Jeffrey A. Lamken

Name: Jeffrey A. Lamken

1. Represented Entities. Fed. Cir. R. 47.4(a)(1).	**2. Real Party in Interest.** Fed. Cir. R. 47.4(a)(2).	**3. Parent Corporations and Stockholders.** Fed. Cir. R. 47.4(a)(3).
Provide the full names of all entities represented by undersigned counsel in this case.	Provide the full names of all real parties in interest for the entities. Do not list the real parties if they are the same as the entities. ☑ None/Not Applicable	Provide the full names of all parent corporations for the entities and all publicly held companies that own 10% or more stock in the entities. ☑ None/Not Applicable
TQ Delta, LLC	None	None

☐ Additional pages attached

4. Legal Representatives. List all law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities. Do not include those who have already entered an appearance in this court. Fed. Cir. R. 47.4(a)(4).

☐ None/Not Applicable ☐ Additional pages attached

Ashley Ratycz formerly of McAndrews, Held & Malloy, Ltd.	Andrew J. Wright Bruster PLLC	Rudolph Fink, IV The Davis Firm, PC
Edward K. Chin Bruster PLLC	Shawn A. Latchford Bruster PLLC	Ty William Wilson The Davis Firm, PC
Anthony K. Bruster Bruster PLLC	Christian J. Hurt formerly of The Davis Firm, PC	William Ellsworth Davis, III The Davis Firm, PC

5. Related Cases. Other than the originating case(s) for this case, are there related or prior cases that meet the criteria under Fed. Cir. R. 47.5(a)?

☑ Yes (file separate notice; see below) ☐ No ☐ N/A (amicus/movant)

If yes, concurrently file a separate Notice of Related Case Information that complies with Fed. Cir. R. 47.5(b). **Please do not duplicate information.** This separate Notice must only be filed with the first Certificate of Interest or, subsequently, if information changes during the pendency of the appeal. Fed. Cir. R. 47.5(b).

6. Organizational Victims and Bankruptcy Cases. Provide any information required under Fed. R. App. P. 26.1(b) (organizational victims in criminal cases) and 26.1(c) (bankruptcy case debtors and trustees). Fed. Cir. R. 47.4(a)(6).

☑ None/Not Applicable ☐ Additional pages attached

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CONFIDENTIAL MATERIAL OMITTED

The image redacted on page 16 depicts confidential source code that was designated attorneys' eyes only under the applicable protective order.

TABLE OF AUTHORITIES

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STATEMENT OF RELATED CASES

No other appeal from the action below was previously before this or any other appellate court. The Court's decision in this appeal may directly affect or be directly affected by the following pending cases: *TQ Delta, LLC v. 2Wire, Inc.*, No. 13-cv-01835 (D. Del.); *TQ Delta, LLC v. ADTRAN Inc.*, No. 14-cv-00954 (D. Del.).

JURISDICTIONAL STATEMENT

The district court had jurisdiction under 28 U.S.C. §§1331, 1338(a). The court entered final judgment on May 3, 2023, and denied post-trial motions on February 15, 2024. Appx1-3; Appx191-224. TQ Delta timely appealed on March 15, 2024. Appx13000-03. This Court has jurisdiction under 28 U.S.C. §1295(a)(1).

STATEMENT OF ISSUES

1. Whether the district court erred in denying JMOL or a new trial on infringement of the ’008 patent, where (a) the parties stipulated the patent is standard-essential and the accused products undisputedly implement the standard, and (b) the expert testimony on infringement was unrebutted—CommScope presented no infringement expert—and CommScope’s only theory of noninfringement was lawyer argument that contradicts the construed claim.

2. Whether the district court erred in construing “flag signal” in the ’835 patent, requiring JMOL or a new trial on the patent’s validity.

3. Whether the district court mis-instructed the jury on the standard governing reasonable royalties, requiring a new trial on damages.

STATEMENT OF THE CASE

I. DSL DEVELOPMENT AND STANDARDS

In the 1990s, digital subscriber line (“DSL”) technology revolutionized internet access. It enabled, for the first time, broadband internet access over ordinary

phone lines. At the time, dial-up internet could reach speeds of only 56 kbps, but DSL can offer speeds over 200 mbps—3,500 times faster. Appx2287; Appx9755.

Critically, DSL allowed reaching those speeds using ubiquitous "twisted pair" copper phone lines. Appx5570(15:16-21). DSL thus allowed phone companies to deploy broadband using "infrastructure that they" already had—over 1.5 billion miles of ordinary phone lines serving virtually every household. Appx4748-49(187:13-188:1). Other ways of providing broadband (*e.g.*, cable and fiber) existed, but those required building "extremely expensive" infrastructure, laying down new cable or fiber, to every household. Appx5570(15:22-24); Appx5576(21:17-21).

More than 500 million people worldwide use DSL, including millions in the United States. Appx4741(180:5); Appx12706. This case involves improvements to DSL technology pioneered by Marcos Tzannes and his team at Aware, Inc.

A. TQ Delta's Patented Improvements to DSL

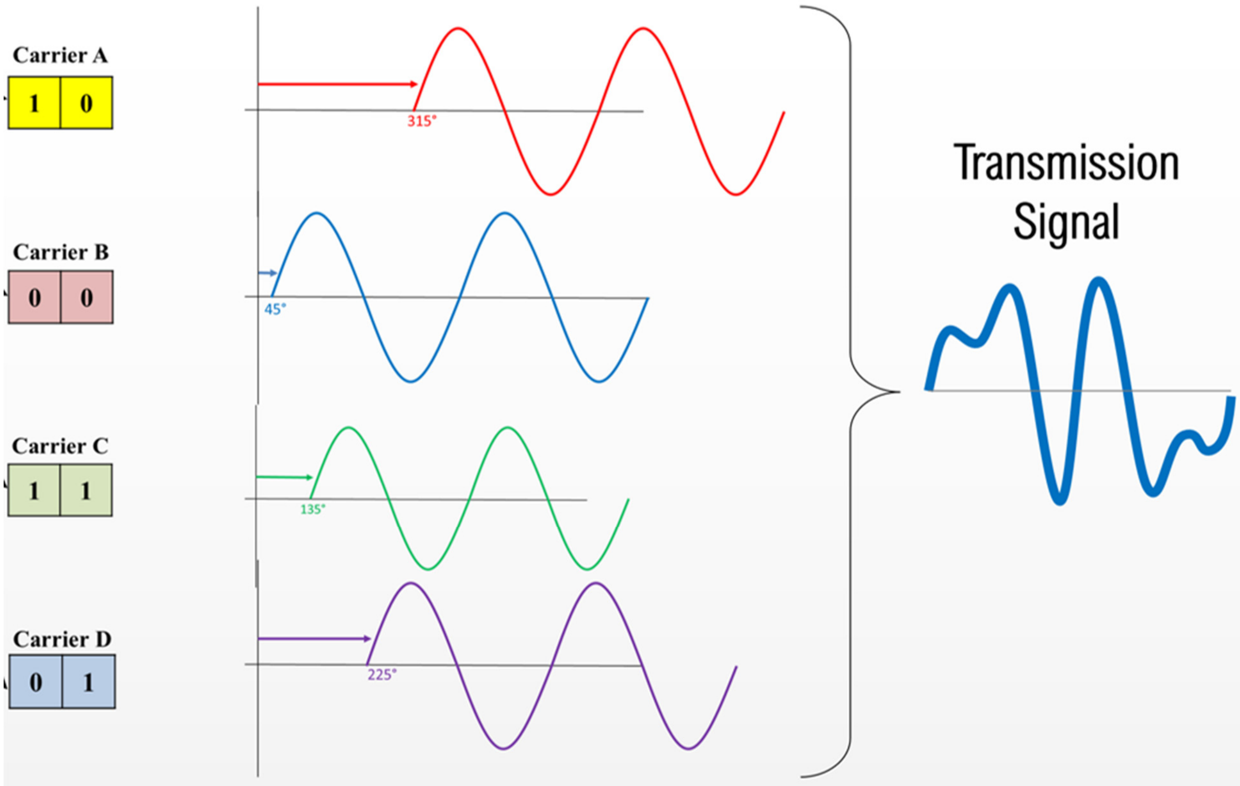
The patents-in-suit cover improvements to DSL technology that enhance speed and reliability. Appx4800(239:1-3); Appx4794-95(233:1-234:2); Appx4798 (237:4-7); Appx5154(304:17-20); Appx5178(328:10-13). For example, the '881 patent teaches an improved technique for "bonding" multiple DSL lines to increase speed. Appx4765-68(204:3-207:22). The '354 patent provides a robust overhead channel ("ROC") to mitigate interference such as "crosstalk" from neighboring

homes' DSL signals. Appx4797-98(237:16-238:21); Appx319(2:21); Appx321 (5:25-36). The '686 patent enables phone companies to diagnose harmful noise on customer phone lines remotely, without sending technicians to customers' homes. Appx4781-82(220:21-221:1); *see* Appx245(3:63-67). And the '048 and '411 patents reduce the amount of memory DSL modems—devices employed to access the internet using DSL—require for various purposes, such as retransmitting corrupted data. Appx4792-93(231:1-232:5); Appx267(1:48-64); Appx4795-97(234:10-236:15); *see* Appx302(1:24-39, 2:10-22).

Two patents—the '008 and '835—are particularly relevant here.

1. *The '008 Patent: Scrambling Carrier Signals*

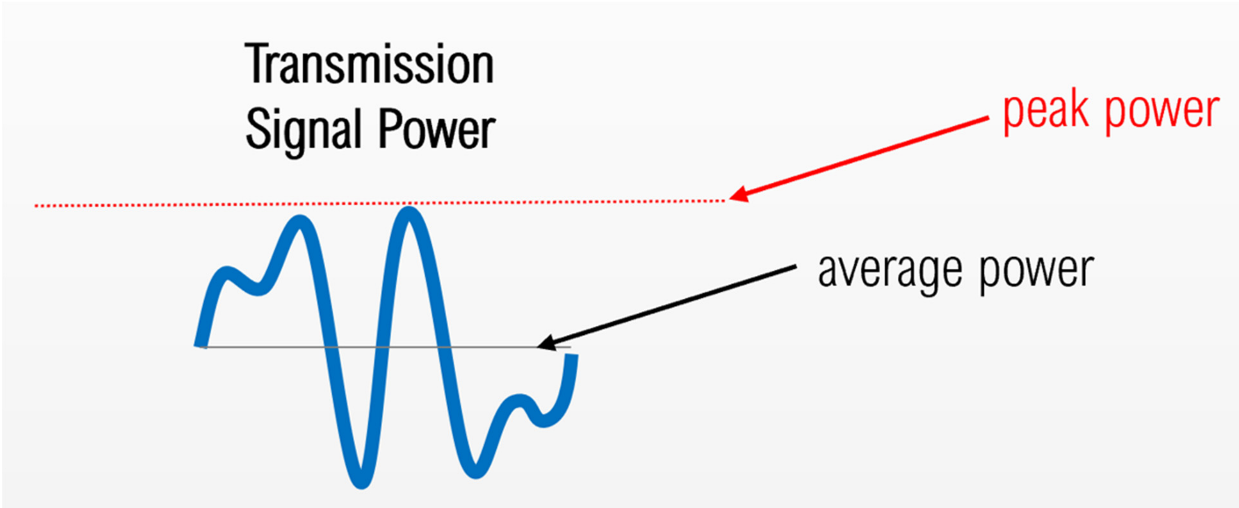
The '008 patent solves problems caused by transmission signals having a high "peak to average power ratio" ("PAR"). Appx4786-87(225:1-226:3); Appx5336(116:20-23). DSL modems represent data by "modulating" (adjusting the "phase" and/or "amplitude" of) electrical "carrier signals." Appx4784-85(223:23-224:12); Appx12613-14. Modems use multiple carrier signals with different frequencies simultaneously (left below), which "add up" to produce a transmission signal (right). Appx4785-86(224:22-225:6).



Appx12616.[1] (In the above graph, amplitude is the wave's height at a given time; phase is the wave's horizontal position on the X-axis.)

As shown below, the transmission signal will have "peaks" wherever the amplitudes of the carriers add up to a high value. The signal's power level at those peaks—its "peak power"—may be much higher than the signal's "average power." Appx255 (1:65-2:2).

[1] The image above shows "time-domain" signals, but other embodiments of the invention may use different mathematical representations for signals.



Appx12620. A transmission signal with a high ratio between peak and average power (*i.e.*, a "high PAR") causes "distortion" in the modem or "clipping" (chopping off) of peaks that reduces signal quality. Appx258(8:23-44); *see* Appx4786-87(225:4-226:3).

The '008 patent "scrambles" the "phase characteristics" of carrier signals to "produce a transmission signal with a reduced [PAR]." Appx255(2:34-48); *see* Appx4784(226:5-9). It teaches computing a "phase shift" for relevant carriers of differing amounts (*e.g.*, pseudorandom amounts), to reduce the probability carrier phases will align such that peaks in each carrier will add up to high peaks in the transmission signal. Appx255(2:55-66); Appx258(7:52-8:11). Those phase-shift amounts are "combined" with (*i.e.*, applied to) the carriers' initial "phase characteristics," and the carriers are added together to create a "scrambled" transmission signal. Appx255(2:34-47).

Claim 14, asserted here, recites:

> [pre] A multicarrier system including a first transceiver that uses a ***plurality of carrier signals*** for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:
>
> [a] ***associating*** each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;
>
> [b] ***computing*** a phase shift for each carrier signal based on the value associated with that carrier signal; and
>
> [c] ***combining*** the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

Appx260 (11:41-12:14) (emphasis added).

2. *The ’835 Patent: Synchronizing Error-Correction Settings*

The ’835 patent discloses an innovative way for DSL transceivers to respond to changing bursts of noise called “impulse noise.” Appx4789-90 (228:20-229:17); Appx284 (3:24-31). DSL modems mitigate data loss from impulse noise by using “Forward Error Correction (FEC)” and “interleaving.” Appx283 (1:34-37). Those techniques involve converting data into “codewords” with redundant bytes that can be used to reconstruct data that becomes corrupted during transmission. Appx283 (1:30-2:51).

Increased impulse noise, however, may exceed the system's error-correction capability. Appx283-84 (1:60-3:16). In that case, the modem must reconfigure the parameters used for FEC and interleaving ("FIP settings") to ones that can handle more noise. Appx283 (1:60-2:67); Appx284 (3:31). The sending and receiving modems must use the same FIP settings, however, so any change in settings must be coordinated. *See* Appx287 (9:19-29). The prior art used a "time consuming" technique that required repeatedly "reinitializ[ing]" the modem using different FIP settings until "service is acceptable." Appx283 (2:43-67).

The '835 patent enables FIP settings to be "reconfigure[d]" on-the-fly. Appx4790 (229:10-13). The receiving and transmitting modems switch between pre-programmed FIP settings in response to a "flag signal." Appx288 (12:8-37). The modems perform the switch simultaneously, after a "predetermined" amount of time "following transmission of the flag." Appx288 (11:66-12:37); Appx293 (21:33-47). The patent describes switching a predetermined amount of time after transmission of a flag as "more desirable" than alternative approaches. Appx288 (12:5-6). For example, one alternative is for the modems to exchange a "message . . . specifying" when to switch; but such a message would contain data that could be lost in transmission. Appx288 (11:30-65); Appx1974 (¶70). A flag signal, by contrast, has no extra data that could be lost in transmission, giving it "greater impulse noise immunity." Appx288 (12:7).

Claim 10 of the ’835 patent, asserted in this case, depends from independent claim 8. Independent claim 8 recites:

> [pre] An apparatus configurable to adapt forward error correction and interleaver parameter (FIP) settings during steady-state communication or initialization comprising:
>
> [a] a transceiver, including a processor, configurable to:
>
> [b] transmit a signal using a first FIP setting,
>
> [c] transmit a flag signal, and
>
> [d] switch to using for transmission, a second FIP setting following transmission of the flag signal,
>
> wherein:
>
> [e] the first FIP setting comprises at least one first FIP value,
>
> [f] the second FIP setting comprises at least one second FIP value, different than the first FIP value, and
>
> [g] the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

Appx293 (21:33-46).

Asserted claim 10 adds the following requirement:

> a first interleaver parameter value of the first FIP setting is different from a second interleaver parameter value of the second FIP setting.

Appx293 (21:51-53).

B. TQ Delta’s Technologies Are Included in ITU Standards for DSL

Industry participants establish global standards for DSL technology through the International Telecommunication Union (“ITU”). Appx4677 (116:6-12);

Appx4752 (191:10-24); Appx4754 (193:3-8). The ITU evaluates new technologies for inclusion in standards, adopting only the "best." Appx4758 (197:1-9). The ITU's approval process requires unanimous "consensus." Appx4761 (200:5-10). "[E]ven a single" member (like Defendant CommScope) can veto changes. Appx4761 (200:5-10); *see* Appx4789 (228:10-12); Appx4756-57 (195:2-196:1).

The ITU recognizes patented technologies play a critical role in standards. When a standard is approved, the ITU receives "declaration[s]" from patentholders informing the industry of patents covering technology included in the standard. Appx4759 (198:4-12). Some of those patents are standard-essential patents ("SEPs")—*i.e.*, the standard cannot be practiced without infringing the SEPs. *See* Appx4677 (116:13-20). The ITU requires SEP owners to license their SEPs on fair, reasonable, and non-discriminatory ("FRAND") terms. Appx4677-78 (116:13-117:4).

Aware, an ITU member, contributed to the DSL standards, and Tzannes participated in ITU meetings on Aware's behalf. *See* Appx4748 (188:8-13); Appx4741 (180:12-22); Appx4752-53 (191:10-192:18); Appx4759 (198:12-14); Appx4782 (221:19-22). The ITU incorporated many of Tzannes and Aware's patented advances into DSL standards, including those in the '008 patent, Appx4789 (228:3-9); '686 patent, Appx4783-84 (222:21-223:8); '354 patent, Appx4799-800 (238:22-239:3); and '835 patent, Appx4791 (230:8-17). The as-

serted patents are now assigned to plaintiff TQ Delta. Appx4740(179:13-22); Appx4743-44(182:14-183:2).

II. COMMSCOPE'S INFRINGING PRODUCTS

CommScope makes DSL modems practicing ITU standards. Appx5475-81(255:1-261:21). CommScope sells modems to phone companies like AT&T, which distribute them to DSL subscribers. *E.g.*, Appx5047-48(197:1-198:19); Appx5053(203:9-21); Appx5147(297:12-21); Appx5332-36(112:9-116:7). Using CommScope's modems, carriers like AT&T can sell customers high-speed internet service over legacy phone lines, without replacing billions of miles of copper lines with expensive new fiber. Appx4748-49(187:15-188:1); Appx4859-61(9:17-11:6); Appx5011-12(161:23-162:5); Appx5476-77(256:1-257:19).

Demand for DSL peaked around 2008—the time of CommScope's "first infringement"—and "held fairly steady" for nearly a decade, Appx5571-72(16:15-17:4), making DSL "critical" to phone companies, Appx5572(17:1-4). During the 2010-2022 period at issue here, CommScope made and sold over 36 million accused DSL modems, many to its "largest customer," AT&T. Appx5600-03(45:10-48:1); Appx5123(273:4-6). CommScope generated "about $3.4 billion" in revenue from those sales. Appx5576(21:10-14).

CommScope also provides "ongoing support," "bug fixes," and "updates," that extend the service life of CommScope's products and induce continued

infringement by carriers and end-users. Appx5124-25 (274:14-275:5); *see* Appx5259-61 (39:24-41:6).

III. PROCEEDINGS BELOW

TQ Delta sued CommScope for direct and induced patent infringement. Appx149-50; Appx4674-76 (113:24-115:7). CommScope counterclaimed, alleging breach of FRAND commitments. Appx192. The jury found most of the asserted patents valid and infringed, and rejected CommScope's FRAND claim. *See* Appx4546-54. As relevant here, however, the jury found the '008 patent valid, but not infringed, and the'835 patent infringed, but not valid. Appx4549-52. The jury awarded TQ Delta a fraction of the requested damages. Appx4552.

A. Infringement ('008 Patent)

The parties stipulated that the '008 patent is essential to the ITU "VDSL2" standard. TQ Delta presented unrebutted evidence CommScope's accused products practiced that standard, and practiced each limitation of asserted claim 14 of the '008 patent. CommScope presented no infringement expert. The jury found non-infringement. Appx4549.

1. *The District Court Adopts a Claim Construction That Expressly Encompasses Some Carriers Having a Phase Shift of 0*

The '008 patent reduces data loss caused by high peak-to-average-power-ratio (PAR) by "scrambl[ing] the phase characteristics" of carrier signals to "produce a transmission signal with a reduced [PAR]." Appx255 (2:34-48). Limitation

14[c] requires "combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially ***scramble the phase characteristics of the plurality of carrier signals***." Appx260(11:41-12:14) (emphasis added).

The district court construed "scramble the phase characteristics of the plurality of carrier signals" by adopting the construction of " 'the Delaware Court' " in *TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-cv-01835, 2018 WL 582111 (D. Del. Jan. 29, 2018) ("*2Wire*"). Appx7-8; Appx66-70. There, the district court had construed that term to mean "adjust the phase characteristics of the carrier signals by varying amounts." Appx68. It had rejected a construction requiring all carriers to "undergo a phase adjustment of a ***non-zero amount***," explaining the claims cover scenarios where "the equation used to determine the adjustment generates a zero." *2Wire*, 2018 WL 582111, at *3 (emphasis added). While CommScope objected to that construction on other grounds, it neither objected to the determination that the claims encompass adjusting some carrier signals by a phase shift of 0, nor sought a contrary construction. Appx989-90; *see* Appx1939-40(111:7-112:24). (2Wire is now CommScope's subsidiary, and the same counsel that represented 2Wire also represented CommScope in the district court here. *See TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-cv-01835 (D. Del.).)

2. *Trial Testimony*

TQ Delta's expert, Dr. Madisetti, testified that CommScope's modems infringe claim 14 using two forms of analysis. Under this Court's precedents, infringement can be established by showing that a patent is standard-essential, and the accused products practice the standard. *Fujitsu Ltd. v. Netgear Inc.*, 620 F.3d 1321, 1327 (Fed. Cir. 2010). Accordingly, Madisetti showed the claim reads on section "12.3.6.2" of the "VDSL2 standard," and the accused products practice section 12.3.6.2. Appx5336-52 (116:24-132:15).

Claim 14 is directed to a system that "uses a plurality of carrier signals for modulating a bit stream" (*i.e.*, encoding data). Appx259 (10:59-64). The standard has 4,096 "subcarriers," each identified by an "index." Appx9853; Appx10021. Madisetti equated the claimed "plurality of carrier signals for modulating a bit stream" with the subset of subcarriers, highlighted in blue below, used to "encode[] the bit stream." Appx5340 (120:15-22).

Table 12-68 –Bit mapping for R-P-MEDLEY with two bytes per DMT symbol

Plurality of Carrier Signals

Subcarrier index	Constellation point
5, 10, 15, ..., 5 *n*, ...	00
1, 11, 21, ... 10 *n* + 1, ...	SOC message bits 0 and 1
2, 12, 22, ... 10 *n* + 2, ...	SOC message bits 2 and 3
3, 13, 23, ... 10 *n* + 3, ...	SOC message bits 4 and 5
4, 14, 24, ... 10 *n* + 4, ...	SOC message bits 6 and 7
6, 16, 26, ... 10 *n* + 6, ...	SOC message bits 8 and 9
7, 17, 27, ... 10 *n* + 7, ...	SOC message bits 10 and 11
8, 18, 28, ... 10 *n* + 8, ...	SOC message bits 12 and 13
9, 19, 29, ... 10 *n* + 9, ...	SOC message bits 14 and 15
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

Appx12636; Appx5340 (120:19-22). As shown above, the subcarriers included in the claimed "plurality of carrier signals" have an index > 0 (left column) and carry "message bits" (right column). The standard also identifies subcarriers, such as those in the top row above, that do not carry data—are not used "for modulating the bit stream." In particular, it specifies a "DC" (direct current) subcarrier that has index = 0. Appx10023; *see* Appx5388 (168:15-17).

Madisetti testified that each claim limitation reads on the standard. The standard requires associating a "two bit[ ]" "pseudorandom" number with each "sub-carrier," satisfying limitation 14[a]'s requirement of "associating" relevant carrier signals "with a value." Appx5342-43 (122:14-123:12). The standard then requires computing a phase shift—in terms of an "angle of rotation"—for each sub-carrier "based on" that value, using the table below, thus satisfying limitation 14[b]'s requirement of "computing a phase shift" for each carrier signal in the

plurality. Appx5345-46(125:6-126:15). For example, a value of "00" yields a phase shift of 0, and "01" yields a phase shift of π/2. Appx10023. Finally, the standard provides that the modulated carriers "shall be pseudorandomly rotated" (*i.e.*, shifted in phase) by that "computed phase shift," satisfying limitation 14[c]'s requirement of "scrambl[ing] the phase characteristics of the plurality of carrier signals." Appx5346-48(126:5-128:23); *see* Appx10023 ("each subcarrier shall be pseudo-randomly rotated by 0, π/2, π, or 3π/2").

Table 12-70 – Pseudo-random transformation

d_{2n}, d_{2n+1}	Angle of rotation	Final coordinates
0 0	0	(X, Y)
0 1	$\pi/2$	$(-Y, X)$
1 1	π	$(-X, -Y)$
1 0	$3\pi/2$	$(Y, -X)$

computing

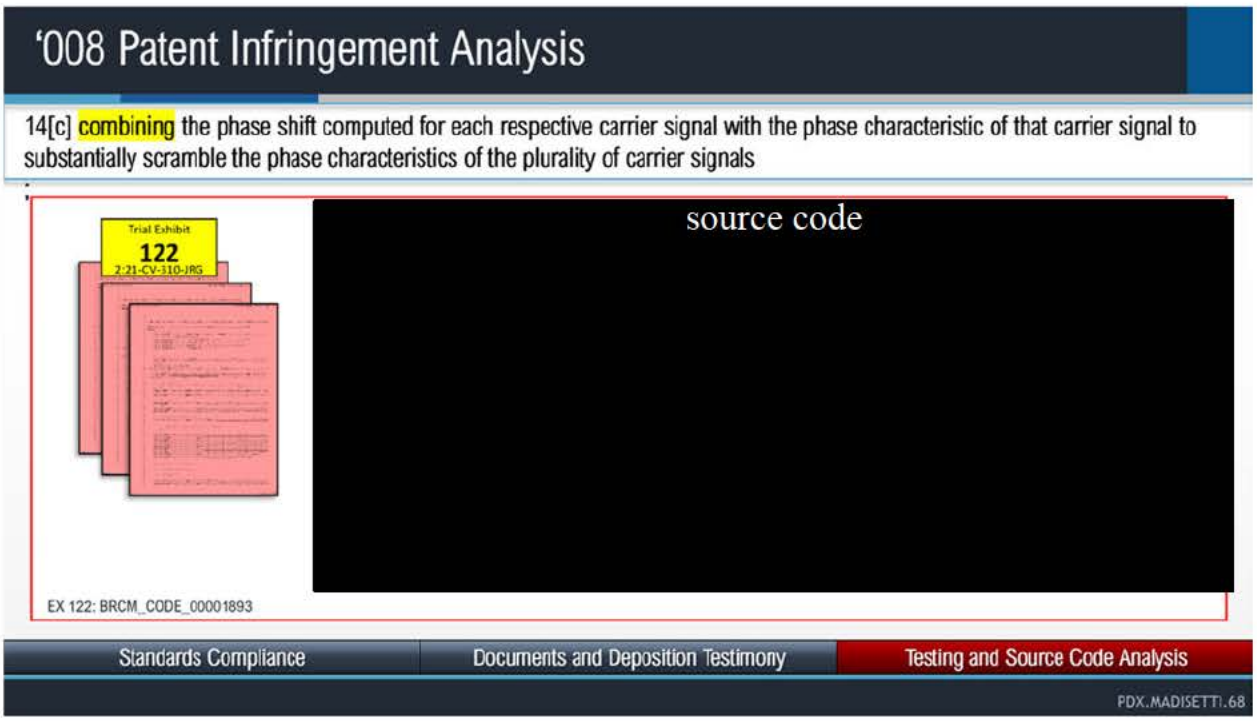
value

phase shift

Appx12648 (reproducing Appx10023).

Madisetti testified the accused devices practice section 12.3.6.2. A witness from third-party Broadcom testified that "section 12.3.6.2 . . . is implemented in all the Broadcom [DSL] chips" used in the accused products. Appx5347(127:21-24). Statements in the chips' "source code" confirmed implementation of "the VDSL2 standard." Appx5344(124:4-25); Appx7619. And AT&T documents showed the accused products met requirements AT&T imposed on suppliers for "compliance with VDSL2." Appx5054(204:19-21).

Apart from the standard, Madissetti testified that the products' "source code" confirms infringement ***directly*** by providing for performance of each limitation. *See* Appx5343-45(123:13-125:3) (limitation 14[a]); Appx12642-46; Appx5346-48(126:23-128:3) (limitation 14[b]); Appx12650; Appx5349-52(129:17-132:15) (limitation 14[c]); Appx12655-58; Appx12662. For example, his demonstrative reproduced below shows how the accused products "scramble the phase characteristics of the plurality of carrier signals" (limitation 14[c]).



Appx12656; *see* Appx5349(129:17-25).

CommScope presented no expert testimony, or other evidence, disputing infringement of claim 14. Its counsel asked Madisetti about a table in the standard, *see* p. 15, *supra*, which provides that, where the value associated with a subcarrier

is "00," the corresponding "[a]ngle of rotation" (phase shift) is 0. Appx5383-84 (163:6-164:25); Appx10023. That did not change Madisetti's opinion, however, because "adding a 0" qualifies as a "rotation" (phase shift). Appx5384-85 (164:18-165:4); Appx70. Counsel also pointed to the "DC" carrier, which the standard specifies "shall not be rotated." Appx5385 (165:14-18); Appx10023. Referring to his chart identifying the claimed "plurality of carrier signals" used to "encode[] the bit stream," Appx5340 (120:15-22), Madisetti explained the DC carrier was not one of the "plurality of carriers" that must be phase shifted, Appx5388 (168:9-21). (To speak of phase-shifting the "DC" carrier would be incoherent: It is a constant-voltage signal that cannot be shifted in phase, and it is not used to modulate a bit stream. Appx5388 (168:9-21); Appx6429; Appx10023.)

In closing, CommScope's counsel did not deny that the accused devices practice the standard, but insisted that they do not infringe because the "standard is different from what the claim requires." Appx6286 (107:6-19). According to him, "the patent . . . requires a phase shift for each carrier signal," but the standard does not require phase-shifting each carrier. Appx6285-86 (106:22-107:19). He pointed to the DC carrier, Appx10023, but did not address Madisetti's testimony that the DC carrier was not one of the plurality of carriers he had identified as being used to modulate the bit stream. Appx6286 (107:9-11); Appx5388 (168:9-21). Counsel also referred to what he called "the four sub-carriers in the standard," and insisted

that "the standard says don't shift one [of them]." Appx6286(107:12-17). But he did not identify anything in the standard stating that the modulated subcarriers—the carriers Madisetti included in the claimed "plurality of carrier signals"—are not rotated by one of the four specified amounts.

3. *The Parties Stipulate and the Jury Is Instructed That the '008 Patent Is Standard-Essential*

Until jury instructions, the parties disputed whether the '008 patent (and others) were standard-essential. On the fourth trial day, the parties submitted draft jury instructions directing the jury to decide whether "the asserted patents are actually essential to any standard." Appx7567; Appx7570-71. In an email to the court that evening, CommScope confirmed its position that the '008 patent was "neither essential nor infringed." Appx7564; *see* Appx209.

On the fifth trial day, the parties again submitted draft instructions leaving standard-essentiality to the jury. Appx7573; Appx7576. The district court then conducted an off-the-record "informal charge conference." Appx6178(249:12-16). There, the parties agreed to stipulate that the '008 patent is standard-essential, as reflected in the revised jury instructions the court circulated the next morning. Appx6361-65; Appx6366-67; Appx6390. Addressing "stipulated . . . facts," the instructions stated the jury must treat "as proven," that "the '008 Patent" is a "'standard essential patent[].'" Appx6364-67. Addressing FRAND commitments, the instructions stated that "the '008 Patent" is an "SEP." Appx6390. And

in the portion addressing reasonable royalties, they stated the ’008 patent was one of the “patents[] which the parties have stipulated are SEPs.” Appx6390. The instructions did not limit those stipulations to any topic or purpose.

The district court then held a formal charge conference, where neither party objected to the instructions reflecting the stipulation. Appx6183-84 (4:20-5:12); Appx6185 (6:11-18); Appx6192 (13:15-18). The jury was so instructed. Appx6204-07 (25:17-28:23); Appx6245-47 (66:25-68:2).

B. Validity (’835 Patent)

The jury found claim 10 of the ’835 patent invalid. Appx4550. That patent requires using a “flag signal” to synchronize FIP settings between sending and receiving modems. Appx293 (21:33-35). Before trial, TQ Delta argued that “flag signal” means a “signal used to indicate when an updated FIP setting / interleaver parameter value is to be used,” where “the signal does not contain message data indicating ***when*** the updated FIP setting / interleaver parameter value is to be used[.]” Appx90 (emphasis added). That distinguished the flag signal from “message[s]” that indicated not only that FIP settings should be changed, but also specified “***when***” to change the settings (in contrast to a pre-determined timing). Appx90 (emphasis added).

The district court agreed that a flag signal “is a signal ***to*** change, not a signal of ***when*** to change.” Appx92. Claim 8, the court explained, requires that “‘the

switching occur[] on a ***pre-defined*** forward error correction codeword boundary ***following the flag signal***.'" Appx93. The court also noted the specification's disclosures that flag-based switching occurs at a "'predefined change time'" or "'on a pre-defined FEC codeword boundary.'" Appx92 (citing Appx288(11:66-12:24)) (emphasis omitted). The specification thus "contrasts" flag signals with "other synchronization methods, such as using codeword counters." Appx93. Those disclosures "demonstrate[] that a 'flag signal' does not ***itself set forth a change time*** but rather is merely an indication that the updated FIP setting / interleaver parameter value should be used at some juncture that is ***pre-defined*** in relation to when the flag signal is received." Appx93 (emphasis added).

Nonetheless, the district court refused to construe "flag signal" to exclude signals that "contain message data indicating ***when*** the updated FIP setting / interleaver parameter value is to be used." Appx90 (emphasis added). It excluded only signals that contain a ***specific type*** of timing data: an "FEC codeword counter value upon which the updated FIP setting is to be used." Appx94. The court provided no explanation. Appx91-94.

CommScope invoked that construction at trial, arguing the '835 patent was obvious in view of prior art where the flag signals concededly "contain information about the timing of parameter changes." Appx5864-65(309:20-310:8); Appx1974-75(¶¶70, 72-73). The jury found the '835 patent invalid. Appx4550.

C. Damages

1. *Trial Testimony*

TQ Delta's expert, Dr. Putnam, presented a reasonable-royalty damages analysis. A reasonable royalty must reflect "'the economic value of the patented technology in the marketplace.'" *Aqua Shield v. Inter Pool Cover Team*, 774 F.3d 766, 771-72 (Fed. Cir. 2014). Putnam valued the patents-at-issue based on the cost savings they generated for phone companies such as AT&T, CommScope's largest customer. Appx5569(14:4-15:2); Appx5572(17:12-14).

Putnam explained that, at the relevant time, phone companies had two options for providing broadband: use TQ Delta's standard-essential technologies to offer DSL over existing phone lines or build "extremely expensive" fiber infrastructure home-by-home. Appx5570-72(15:16-17:25); Appx5576(21:17-21).[2] He calculated the "incremental value" of DSL by determining the costs avoided by choosing DSL over fiber. Appx5573(18:3-7); Appx5577(22:4-15). Putnam calculated those savings at $135.97/device. Appx5582-85(27:25-30:23).

Putnam then analyzed a hypothetical negotiation between SEP-holders (including TQ Delta) and "implementers" (including CommScope). Appx5585-86(30:25-31:13). He concluded that, given their respective bargaining positions, they would agree on a $67.99/device royalty for all DSL SEPs. Appx5586-

[2] Cable was "not an alternative" for phone companies because it would require "mixing" incompatible technologies. Appx5572(17:17-25).

88 (31:23-33:3). That share would be divided among 205 standard-essential patent families, resulting in an average FRAND royalty of $0.33 per patent family. Appx5588-94 (33:10-39:23).

Putnam opined that TQ Delta's SEPs would be valued in the "top 50 percent" of relevant SEPs, but conservatively assigned each asserted SEP the $0.33/device "average value." Appx5594 (39:8-23); Appx5597-5598 (42:7-43:18). Moreover, although TQ Delta's ***non***-SEPs yielded cost savings of $0.71/device, Putnam concluded the most commercially reasonable option would have been to license them with the SEPs at the same rate. Appx5595-97 (40:13-42:3). After various adjustments, Putman concluded the parties would have negotiated a royalty amounting to $89.1 million. Appx5598-603 (43:14-48:1).

2. *Jury Instructions*

There was no dispute that TQ Delta's expert Putnam valued the patents based on ***phone-company*** cost savings, not ***CommScope's*** cost savings. CommScope's attorneys and witnesses repeatedly described Putman's testimony that way. *See, e.g.*, Appx2236-37; Appx5658 (103:15-25); Appx5660 (105:14-16); Appx6003 (74:16-20); Appx6027-28 (98:13-99:3); Appx6174 (245:6-8). The parties' proposed damages instructions—submitted at the district court's request the evening before the last trial day, Appx6413—reflected that understanding. TQ Delta proposed instructing the jury that its "expert has proposed a cost-savings

model that values the accused products CommScope ***provides to its customers***." Appx6413 (emphasis added). "'Reliance upon estimated cost savings ***from use*** of the infringing product,'" the instruction continued, "'is a well-settled method of determining a reasonable royalty.'" Appx6413 (emphasis added) (quoting *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075 (Fed. Cir. 1983)). CommScope's proposed instruction similarly stated that a reasonable royalty could be based on "estimated cost savings from ***use*** of the infringing product." Appx6412 (emphasis added).

The draft jury instructions the district court circulated the next morning rejected both proposals. The court's instructions, *sua sponte*, limited TQ Delta's damages to ***CommScope's*** cost savings—excluding savings to CommScope's customers from use of infringing products. *See* Appx6361; Appx6386. They characterized Putnam's damages model as "rel[ying] upon estimated costs, if any, that ***CommScope*** saved[.]" Appx6386 (emphasis added). They told the jury to "focus on whether ***CommScope's*** make, use, or sale of the patented technology allowed ***it*** to avoid taking a different, more costly course of action, and if so, how much ***CommScope*** saved by using the Accused Products." Appx6386 (emphasis added).

At the formal charge conference—held 45 minutes after the court circulated draft instructions with the court's changes to the damages instruction—both parties

objected. Appx6180; Appx6189-90(10:14-11:15). TQ Delta objected to the description of its damages model as "rely[ing] upon estimated costs . . . that ***CommScope***" saved, and the direction to "focus on whether ***CommScope's***" use of the technology allowed "***it*** to avoid" costs. Appx6189-90(10:16-11:6); Appx6386 (emphasis added). TQ Delta proposed alterations eliminating the directive that only CommScope's cost-savings mattered or should be the focus. Appx6189-90(10:16-11:6); Appx6386. CommScope objected to "the same paragraph." Appx6190(11:12-15). The district court overruled both objections. Appx6190(11:12); Appx6238-39(59:17-60:4).

CommScope's closing argument exploited the instructions: "The law," it told the jury, required "assess[ing] . . . the benefit" to "CommScope, ***not*** to the carrier like AT&T." Appx6292(113:22-24) (emphasis added). The jury returned a damages verdict in the amount of $11.1 million. Appx4552.

D. The District Court Denies TQ Delta's Post-Trial Motions

The district court denied TQ Delta's post-trial motions. Appx149; Appx166; Appx208; Appx1-3.

1. *Infringement ('008 Patent)*

The district court denied TQ Delta's motion for JMOL and/or a new trial on infringement of claim 14 of the '008 patent. Appx215. Because the parties had stipulated that the '008 patent was essential to the VDSL2 standard, and unrebutted

evidence showed the accused products practice that standard, TQ Delta urged infringement was established as a matter of law. Appx6425-26. The district court nowhere disagreed that the accused products practice the standard. But it urged that CommScope "never stipulated to the standard essentiality of the '008 patent for infringement purposes," agreeing with CommScope's argument that the stipulation "applie[d] only in the patent damages context." Appx215.

The court pointed to nothing in the jury instructions so limiting the stipulation's scope. It invoked an email from CommScope's counsel, sent before the informal charge conference—before any agreement, when the parties still disputed essentiality for all issues. Appx215 (citing Appx7564). In that email, CommScope argued that, although it disputed whether the patents were standard-essential, damages for infringement would be subject to FRAND limits anyway: ***If*** the jury found the '008 patent infringed, it urged, "then the patent must, by definition, be essential and subject to TQ Delta's RAND commitment." Appx7564. The court, however, did not identify anything suggesting it or the parties had adopted that argument (which ignored TQ Delta's evidence of infringement apart from standard-essentiality). Nor did the court explain how a reasonable jury hearing the instructions as given could have understood them to be limited to damages.

Madisetti had testified to infringement, limitation by limitation. The district court did not identify any deficiency. It did not point to contrary testimony;

CommScope presented no infringement expert. CommScope argued only that the jury could have found non-infringement based on the requirement that the accused products "adjust the phase characteristics of the carrier signals by varying amounts"; in the standard and accused products, it urged, some carriers are only shifted by "zero." Appx219-20. The district court made no effort to reconcile that argument with the claim construction it had adopted, which expressly allowed a phase shift of zero for certain carrier signals. *2Wire*, 2018 WL 582111, at *3. And the court did not dispute that the "DC" carrier had no phase to adjust, because it is a constant, "direct current." Appx6429; Appx222. Indeed, it offered no analysis at all. It simply declared that TQ Delta's evidence was not "so overwhelming that it required the Jury to find standard essentiality." Appx223.

2. *Damages*

The district court denied TQ Delta's motion for a new damages trial, rejecting its argument that the court's damages instruction erroneously limited the jury to evaluating how much "'***CommScope*** saved'" by infringing. Appx6342-45 (emphasis added); Appx166. The court ruled that TQ Delta's objection at the formal charge conference was "[in]sufficiently specific." Appx173. On the merits, the court acknowledged that Putnam's model "relied on the cost savings that AT&T, CommScope's customer, realized." Appx171. It agreed that Comm-Scope had "pointed to no precedent affirmatively holding that the cost-savings

approach is limited to the cost savings of the defendant." Appx176. The court nevertheless concluded its instruction was "grounded in Federal Circuit precedent and legally accurate." Appx176-77.

The district court also declared TQ Delta was not prejudiced because the instruction permitted the jury to consider "cost-savings to AT&T" as "attributable to CommScope." Appx179. But it pointed to nothing in the instructions allowing the jury to attribute AT&T's savings to CommScope. The court also found the jury "did not take only CommScope's damages model into account," because it awarded a number "between" TQ Delta's and CommScope's proposals. Appx179.

SUMMARY OF ARGUMENT

I. A. TQ Delta is entitled to judgment of infringement of the '008 patent. The parties stipulated, and the jury was instructed, that the '008 patent is "standard essential." Unrebutted evidence established that CommScope's accused products practice the VDSL2 standard. On that record, there was no substantial evidence to support a verdict of non-infringement. The district court reached a contrary result only by impermissibly re-writing the parties' stipulation. Nothing the court cited supported the effort to narrow the stipulation to apply only to damages issues.

B. Even apart from the stipulation, TQ Delta offered unrebutted expert testimony that the accused products infringe. CommScope put up no witness—lay or expert—to testify to noninfringement. Its only theory of non-infringement,

articulated for the first time through attorney argument during closing, contravened the court's claim construction. Non-infringement theories that contradict claim constructions cannot sustain a verdict. And under Fifth Circuit law juries may not disregard unequivocal, unimpeached expert testimony on technical matters based on faulty attorney argument.

II. JMOL or a new trial is required on the '835 patent's validity. In construing the '835 patent's "flag signal" limitation, the district court agreed that a "flag signal" "is a signal ***to*** change, not a signal of ***when*** to change." Appx92. But it inexplicably adopted a contrary construction irreconcilable with the patent.

III. A new damages trial is required. TQ Delta's damages expert properly determined the incremental value of the patented technology by the cost savings it generated for CommScope's customers. Yet the district court instructed the jury to consider only CommScope's own cost savings. That defies the law and facts. It also gutted TQ Delta's damages case.

STANDARDS OF REVIEW

The denial of JMOL is reviewed *de novo*. *Apache Deepwater, L.L.C. v. W&T Offshore, Inc.*, 930 F.3d 647, 653 (5th Cir. 2019); *see Abbott Labs. v. Syntron Bioresearch, Inc.*, 334 F.3d 1343, 1349 (Fed. Cir. 2003). The denial of a new trial is reviewed for abuse of discretion. *Clapper v. Am. Realty Invs., Inc.*, 95 F.4th 309, 313 (5th Cir. 2024).

Interpretations of patent claims, party stipulations, and jury instructions are all reviewed *de novo*. *Intel Corp. v. Qualcomm Inc.*, 21 F.4th 801, 808 (Fed. Cir. 2021) (claim construction); *Enriquez-Gutierrez v. Holder*, 612 F.3d 400, 411 (5th Cir. 2010) (stipulations); *see Hewlett-Packard Co. v. Mustek Sys., Inc.*, 340 F.3d 1314, 1321 (Fed. Cir. 2003) (jury instructions).

Whether jury instructions correctly state the law is reviewed *de novo*. *Barry v. Medtronic, Inc.*, 914 F.3d 1310, 1332 (Fed. Cir. 2019) (Fifth Circuit law for non-patent issues); *Sulzer Textil A.G. v. Picanol N.V.*, 358 F.3d 1356, 1363 (Fed. Cir. 2004) (Federal Circuit law for patent issues). Instructions are reviewed for abuse of discretion where objections are preserved, or plain error otherwise. *Garcia-Ascanio v. Spring Indep. Sch. Dist.*, 74 F.4th 305, 309 (5th Cir. 2023).

ARGUMENT

I. THE DISTRICT COURT ERRED IN DENYING JMOL OR A NEW TRIAL ON INFRINGEMENT OF THE ’008 PATENT

CommScope stipulated that the ’008 patent was essential to the VDSL2 standard. And everyone agreed the accused products practiced that standard. That established infringement as a matter of law. JMOL is warranted where a “party has been fully heard on an issue” and “a reasonable jury would not have a legally sufficient evidentiary basis to find for the party on that issue.” Fed. R. Civ. P. 50(a)(1); *see Wi-Lan, Inc. v. Apple, Inc.*, 811 F.3d 455, 465 (Fed. Cir. 2016). The district court reached the opposite result only by narrowing the stipulation to less

than it actually said. Settled law precludes departing from a stipulation's clear text. And CommScope presented no expert—in this highly technical case—willing to testify that the accused products do not infringe. Its only theory of non-infringement defies the claims, the district court's unchallenged construction, and physics.

A. The Parties' Standard-Essentiality Stipulation Required JMOL

As this Court has explained, "[i]nfringement can be proven based on an accused product's use of an industry standard if the asserted claim is standard essential." *INVT SPE LLC v. ITC*, 46 F.4th 1361, 1377 (Fed. Cir. 2022). That principle required judgment of infringement here. The parties stipulated the '008 patent is standard-essential. The jury thus was instructed—with no objection from CommScope—to treat standard-essentiality "as proven"; and there was undisputed evidence that the accused products implement the standard. The district court's denial of JMOL—based on CommScope's assertions about its ***intention*** to stipulate only to essentiality for damages, not infringement—defies precedent and reality alike.

1. The stipulation that the '008 patent was essential to the ITU's VDSL2 standard is set forth in the unambiguous and unobjected-to jury instructions. The jury was instructed that "the parties in this case have stipulated" to certain "facts." Appx6204(25:21-22). One of them was that five asserted patents—including "the '008 Patent"—"are subject to commitments with the [ITU]" and "are . . . referred

to as standard essential patents." Appx6207(28:17-23). In a portion of the instructions addressing TQ Delta's "FRAND commitment," the court repeated that the "parties have stipulated that . . . the '008 Patent" and four others "are standard essential patents." Appx6245-46(66:23-67:3). And when addressing damages, the court again referenced "the standard essential patents that the parties have stipulated to, *i.e.*, . . . the '008." Appx6246-47(67:24-68:2).

That stipulation conclusively established that the '008 patent was standard-essential. Whether a patent is standard-essential is a "fact issue." *Godo Kaisha IP Bridge 1 v. TCL Commc'n Tech. Holdings Ltd.*, 967 F.3d 1380, 1385 (Fed. Cir. 2020). Where the parties "stipulate[]" to a fact—as they did here—that withdraws it from the jury, "'dispensing wholly with the need for proof.'" *Christian Legal Soc'y Chapter of the Univ. of Cal. v. Martinez*, 561 U.S. 661, 677-78 (2010). Here, the stipulation withdrew standard-essentiality from the jury. The jury was required to treat that fact "as proven." Appx6204(25:18-21).

Neither the parties nor the district court disputed, moreover, that the accused products "practice the standard." *Fujitsu Ltd. v. Netgear Inc.*, 620 F.3d 1321, 1327 (Fed. Cir. 2010); *INVT*, 46 F.4th at 1377. A witness testified that the DSL chips in the accused products "implement . . . the VDSL2 standard." Appx5112(262:9-18); Appx5113-16(263:23-266:19). TQ Delta's expert testified the products practice the standard, identifying (among other things) "source code specifications"

professing adherence to the standard. Appx5333-36(113:6-116:7); *see* Appx5341-42(121:19-122:8); Appx5347-49(127:21-129:25); Appx5351-52(131:13-132:10). No witness or document said anything to the contrary. Given those "undisputed" facts, no reasonable jury could find that the accused products ***do not practice*** the standard. *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 930 F.3d 1295, 1309 (Fed. Cir. 2019); *see Ericsson, Inc. v. D-Link Sys., Inc.*, 773 F.3d 1201, 1223 (Fed. Cir. 2014).

That should have been conclusive. Standard-essential patents are ***necessarily infringed*** by such standard-compliant products. *INVT*, 46 F.4th at 1377. As the district court instructed the jury, a "standard essential patent" is one where "it would not be technically possible to implement the standard without infringing the patent." Appx4677(116:13-16); *see Fujitsu*, 620 F.3d at 1327; *INVT*, 46 F.4th at 1377. Here, the parties stipulated the '008 patent was standard-essential. And the accused products undisputedly implemented that standard. Infringement followed as a matter of law. *Minn. Mining & Mfg. Co. v. Chemque, Inc.*, 303 F.3d 1294, 1305 (Fed. Cir. 2002).

2. The district court did not deny that, ***if*** the '008 patent were standard-essential, an infringement finding was required. It instead refused to enter judgment of infringement on the theory that the essentiality stipulation was "conditional" and applied only to "damages" after the jury "first found infringement and validity." Appx215-16. But the meaning of a "stipulation" is determined by "the lan-

guage of the agreement memorializing" the agreement—here, the unobjected-to jury instructions. *Kearns v. Chrysler Corp.*, 32 F.3d 1541, 1545 (Fed. Cir. 1994). Like "contracts," "stipulation[s]" are construed within the "'four corners' of the agreement itself." *Wash. Hospital v. White*, 889 F.2d 1294, 1300 (3d Cir. 1989); *see Assoc. Milk Producers, Inc. v. NLRB*, 193 F.3d 539, 544 (D.C. Cir. 1999); *Kearns*, 32 F.3d at 1545 ("stipulation" interpreted like "any contract"). The court identified nothing in the stipulation limiting it to the issue of "damages," after the jury first found infringement.

To the contrary, the stipulation first appeared in a general recitation of "facts" the parties "have stipulated to." Appx6204(25:17-22). It stated that "the '008 Patent" and four other patents "***are*** subject to commitments with the [ITU]" and "***are*** . . . referred to as standard essential patents." Appx6207(28:17-21) (emphasis added). That is clear as can be. Indeed, the stipulation continued: "The '048 Patent and the '411 Patent are not standard essential." Appx6207(28:22-23). Those clear and unequivocal statements do not limit or condition the stipulation's scope. The fourteen other recited stipulations were likewise unconditional facts, such as the parties being "Delaware" corporations. Appx6205(26:15-23).

The district court, moreover, repeated the stipulation two more times:

> In light of this FRAND commitment . . . I have referred at times in these instructions to SEPs[.] . . . ***The parties have stipulated*** that . . . the '008 Patent [and others] . . . are standard essential patents[.]

> . . . [A] reasonable royalty on ***the standard essential patents that the parties have stipulated to***, *i.e.*, . . . the ’008 [and others] . . . cannot exceed the amount permitted under TQ Delta’s FRAND obligations.

Appx6245-46 (66:23-67:3); Appx6246-47 (67:24-68:3) (emphasis added). Those statements do not limit the stipulation to “damages.” Appx215. They unconditionally assert that the listed patents, including the ’008, “***are*** standard essential.” Appx6245-46 (66:23-67:3) (emphasis added). While they reiterate the stipulation in connection with FRAND, they nowhere limit the stipulation to that context. Nor do they revoke the prior instruction—in a portion of the instructions dealing with stipulations generally—that the patent is standard-essential. A reasonable juror could not understand the instructions to limit the stipulation to FRAND issues. *See Kansas v. Carr*, 577 U.S. 108, 122 (2016); *Hewlett-Packard*, 340 F.3d at 1321.

Indeed, when stipulations are provided or evidence is admitted only for a “limited purpose,” courts issue “limiting instruction[s].” *Samia v. United States*, 599 U.S. 635, 646 (2023); *see Sprint Commc’ns Co., L.P. v. Time Warner Cable, Inc.*, 760 F. App’x 977, 981 (Fed. Cir. 2019). CommScope never asked for one. And it never objected to the stipulation as given. That, too, speaks volumes.

3. The district court accepted CommScope’s assertion “that it never stipulated to the standard essentiality of the ’008 Patent for infringement purposes,” pointing to an email from CommScope’s counsel that supposedly “clarifie[d]” that “essentiality was agreed to only . . . for the purposes of FRAND damages.”

Appx215. But the stipulation—the "four corners of the agreement"—controls. *White*, 889 F.2d at 1300. "[E]xtrinsic evidence" is relevant to the meaning of stipulations only where the stipulation is "ambiguous." *Id.* at 1299-1300; *see Assoc. Milk Producers*, 193 F.3d at 544; *Nelson v. Comm'r of Internal Revenue*, 17 F.4th 556, 562 (5th Cir. 2021). Here, the stipulation is unambiguous.

Regardless, CommScope's email was sent before the stipulation was reached and simply restated its pre-stipulation position. CommScope disputed standard-essentiality, but insisted that, if the jury ***were*** to find the '008 patent infringed, "then the patent must, by definition, be essential and subject to TQ Delta's RAND commitment." Appx7564; *see* Appx209; Appx214-15; Appx7576. But TQ Delta disagreed—it showed infringement directly; the jury could find infringement without finding standard-essentiality. Appx6426-27; pp. 16-18, *supra*. A pre-agreement email laying out CommScope's side of a disputed issue sheds zero light on what the parties meant by a subsequent stipulation to resolve that issue.

The district court's reliance on the text of the verdict form, which asked the jury to decide infringement, Appx215, defies the Federal Rules. Rule 50 provides that issues are sometimes submitted to the jury despite one party's entitlement to judgment (perhaps in the hope the jury gets it right; that is why there is a Rule 50(a) ***and*** a Rule 50(b)). Regardless, infringement remained an issue because there

was no stipulation that the accused products implement the standard. It just turned out that, after all the evidence came in, the issue was uncontested.[3]

CommScope's narrative—its effort to explain why the stipulation would be limited to only breach-of-FRAND or damages issues—confirms the error. CommScope had good reason to agree to an unconditional, across-the-board stipulation. By the time of the informal charge conference, after evidence but before closings, CommScope had all but conceded infringement. In a highly technical case, it had presented ***no witness*** denying infringement. But it still had an "important" breach-of-FRAND claim. Appx6280(101:23); Appx6271-82(92:11-103:23). Because TQ Delta showed infringement based both on the accused products practicing the standard ***and*** the products' source code, CommScope risked having the jury find the '008 patent infringed without finding it standard-essential—destroying its FRAND-based arguments. Stipulating to standard-essentiality unconditionally made its FRAND defenses relevant ***regardless*** (and simplified their jury presentation).

Conversely, TQ Delta had ***no*** reason to agree to a conditional stipulation inapplicable to infringement. Stipulating to essentiality ***only*** as to damages would have subjected TQ Delta to CommScope's FRAND ***defense*** and FRAND ***limits*** on

[3] The district court did not suggest that anything said at the off-the-record informal charge conference limited the stipulation's scope; nothing did. Besides, the unambiguous terms of the stipulation foreclose any departure from its terms. Unknowable "language" from off-the-record statements cannot be considered regardless. *United States v. Redd*, 355 F.3d 866, 875 & n.8 (5th Cir. 2003).

damages with ***no corresponding benefit*** to TQ Delta. Under CommScope's telling of the events, the supposedly joint stipulation did not reflect a compromise, but unilateral surrender by TQ Delta.

B. The Verdict Is Not Supported by Substantial Evidence Even Without the Stipulation

Wholly apart from the stipulation, TQ Delta was entitled to judgment of infringement. In patent cases, judgment is required if "substantial evidence" to "support[ ] the jury's verdict under the issued [claim] construction" is lacking. *Wi-LAN*, 811 F.3d at 465. TQ Delta's expert, Madissetti, testified without contradiction that CommScope's products infringe. CommScope put up ***no witness*** (expert or lay) to say otherwise. CommScope's sole "defense" was pointing to the possibility that some carriers will be shifted by a 0-degree angle of rotation under certain conditions. But the claim construction and the claims themselves foreclose that (never disclosed) non-infringement theory: There is no requirement of a non-zero-amount phase shift for every carrier. To the contrary, the court's construction and the claims expressly permit carriers with a phase shift of zero. That foreclosed CommScope's only non-infringement theory from being substantial evidence.

1. *The Claim Construction and Claim Language Foreclosed CommScope's Non-Infringement Arguments*

Madisetti testified to infringement under ***two*** theories. First, as explained above, he testified (consistent with the stipulation) that the accused products

implement § 12.3.6.2 of the VDSL2 standard, and the ’008 patent (specifically, claim 14) is essential to that standard—the standard cannot be practiced without infringing. Appx5340-52 (120:17-132:15); pp. 13-15, *supra*. But Madisetti did not stop there: He performed a limitation-by-limitation analysis of the products’ “source code” to show infringement directly. Appx5339-52 (119:23-132:15); pp. 16-18, *supra*. And he presented “simulations” showing the “phase scrambling” in the accused products achieves a “substantial reduction” in the “PAR”—the very benefit the invention provides. Appx5350-51 (130:20-131:8).

CommScope put up no expert to dispute infringement. Nor did it present a lay witness to contest infringement. Its countervailing evidence consisted of attorney argument related to the requirement that carrier “phase characteristics” be “adjust[ed] . . . by varying amounts.” Appx66-70. In particular, counsel pointed to two statements in the standard suggesting that, for some carriers or in some instances, the phase-shift amount could be zero:

- <u>Table 12-70</u>: Table 12-70 specifies that, where the pseudorandom value associated with a sub-carrier is “00,” the corresponding “angle of rotation” (phase shift) is “0.” Appx5383-84 (163:2-164:25).
- <u>DC Carrier</u>: The standard states that the “DC” subcarrier “shall not be rotated.” Appx5385 (165:14-18).

Thus, in closing arguments, CommScope’s counsel argued for the first time that the claims do not read on the standard, because the standard allows some of the (many) sub-carriers to have a rotation (phase shift) of zero. Appx6286 (107:9-19).

He asserted (incorrectly) that "the standard" has "four sub-carriers," and that "the standard says don't shift one." Appx6286(107:14-16). "[S]hifting three out of four" carriers, he urged, "is different from what the claim requires." Appx6286(107:16-19). As CommScope explained in opposing JMOL, its theory was that the claims ***exclude*** "a phase shift of zero." Appx7659; *see* Appx7659 (arguing jury could have found "zero is not an 'amount'"). That theory was legally insufficient to support the non-infringement verdict.

<u>The claim construction expressly permits a non-zero shift</u>. A "jury verdict" must be "test[ed]" against the "issued construction." *Wi-LAN*, 811 F.3d at 465; *see Hewlett-Packard*, 340 F.3d at 1321. Where proffered non-infringement evidence is irrelevant under that construction, it cannot "rebut . . . substantial evidence of infringement." *LNP Eng'g Plastics, Inc. v. Miller Waste Mills, Inc.*, 275 F.3d 1347, 1357 (Fed. Cir. 2001); *see Mycogen Plant Science, Inc. v. Monsanto Co.*, 243 F.3d 1316, 1326 (Fed. Cir. 2001) (affirming JMOL grant because "jury's findings of non-infringement" lacked "legally sufficient evidentiary basis"). Evidence does not "create a factual dispute" where it "rests on an incorrect claim interpretation." *Wiener v. NEC Elecs., Inc.*, 102 F.3d 534, 542 (Fed. Cir. 1996).

Here, the district court adopted the construction issued by the District of Delaware in *2Wire*, which construed the claims to require "'adjust[ing] the phase characteristics of the carrier signals by varying ***amounts***.'" Appx68 (emphasis

added). In so doing, the Delaware court ***expressly rejected*** a construction requiring "phase adjustment of a ***non-zero*** amount." 2018 WL 582111, at *3 (emphasis added). Its adopted construction instead covered instances where the "equation used to determine the adjustment generates a ***zero***." *Id.* (emphasis added). The district court here nowhere suggested it was adopting that construction but would give its words a different meaning. *Cf. Taggart v. Lorenzen*, 587 U.S. 554, 560 (2019). To the contrary, the district court made clear it was not "departing from the construction reached by the District of Delaware." Appx69.

That construction demolishes CommScope's theory that the existence of zero-amount phase adjustments defeats infringement. Appx7659. Under the court's construction, a carrier can have a phase shift of zero. Madisetti thus explained that the possibility of a zero-amount phase shift for some carriers did not "change [his] infringement opinion." Appx5388(168:18-21). Among other things, "rotating by 0" is still a "rotation"; it still constitutes a phase shift by an amount, Appx5384-85(164:18-165:4), as the claim construction required, Appx70. The conflict between counsel's theory that every carrier signal must be shifted a "non-***zero*** amount" and the claim construction—which expressly allows zero-amount—explains why CommScope never disclosed such a non-infringement theory in expert reports or presented an expert to support it at trial. *See* Appx5755-56(200:18-201:14). It was utterly foreclosed.

The construction's plain language is unambiguous. Claims must be read as a "skilled artisan" would read them, in view of the "patent." *Intel Corp. v. Qualcomm Inc.*, 21 F.4th 784, 791 (Fed. Cir. 2021). No reasonable jury following that rule could have found that the claims here require a non-zero phase shift for every carrier. The construction requires "adjust[ing] the phase characteristics of the carrier signals by varying ***amounts***." Appx70 (emphasis added). CommScope's view that "'zero is not an amount,'" Appx221, is nonsensical. An "amount" is a "number." *Amount*, *American Heritage Dictionary* 62 (3d ed. 1994). Zero is a number. The "amount of money" in a bank account can be zero.

The very fact that, in describing a non-zero amount, one adds the qualifier "non-zero," makes clear that amounts and values otherwise include zero. *See, e.g.*, *Fujitsu*, 620 F.3d at 1334 ("non-zero amount of time"); *MSM Invs. Co., LLC v. Carolwood Corp.*, 259 F.3d 1335, 1340 (Fed. Cir. 2001) ("nonzero amount" of chemical); *Lodestar Anstalt v. Bacardi & Co. Ltd.*, 31 F.4th 1228, 1255 (9th Cir.) ("non-zero amount of sales revenue"); *2Wire*, 2018 WL 582111, at *3.

The specification is equally clear: An "adjust[ment]" of zero to "the phase characteristics of [a] . . . carrier signal" does not place a product outside the claims. The specification discloses equations for computing phase shifts, ***all*** of which produce a phase shift of 0 under certain conditions. Appx257-58 (6:59-8:23). For example, it discloses $(X_N) \times \frac{\pi}{6}\ mod\ 2\pi$, where X_N is a pseudorandom integer and

mod is the modulus (remainder) operator. Appx258(7:54-67). That equation results in 0 whenever X_N is a multiple of 12 (because $(X_N) \times \frac{\pi}{6}$ will be a multiple of 2π, and dividing any multiple of 2π by 2π will result in a remainder of 0). A construction that always requires non-zero phase shifts would improperly exclude ***every specification embodiment***. *Accent Packaging, Inc. v. Leggett & Platt, Inc.*, 707 F.3d 1318, 1326 (Fed. Cir. 2013).

The "extrinsic evidence" is in accord. *Intel*, 21 F.4th at 791. Here, the strongest extrinsic evidence is the standard. It states that "each subcarrier shall be pseudo-randomly ***rotated***"—phase shifted, Appx5383(163:6-9) (emphasis added)—"by ***0***, π/2, π, or 3π/2." Appx10023 (emphasis added). That language would make no sense if 0 was not a valid amount by which a signal could be "rotated." The standard also disposes of CommScope's attorney argument—analogizing phase shifts to rotating the hands of a clock—that a 0-degree adjustment does not constitute "a rotation." Appx5384. The standard plainly calls adjustments of "***0***, π/2, π, or 3π/2" all "***rotat[ions]***." Appx10023 (emphasis added).

Here, the ***sole*** evidence probative of how a "***skilled artisan***" would read the claim language showed that the patents encompass phase shifts of 0. A reasonable jury could not possibly conclude otherwise.

2. *CommScope's Theory Contravenes the Claims in Yet Another Respect*

Claim 14 is directed to a "system" that "uses a ***plurality of carrier signals*** for ***modulating a bit stream***." Appx259(10:58-65) (emphasis added). In the plurality of carrier signals, a phase shift is computed for "each carrier signal," limitation 14[b], and "the phase characteristics of the plurality of carrier signals" are "scramble[d]" (phase shifted), limitation 14[c]. *See Pacing Techs., LLC v. Garmin Int'l, Inc.*, 778 F.3d 1021, 1024 (Fed. Cir. 2015).

Consistent with that, Madisetti identified a subset of the standard's "sub-carriers" as the claimed plurality of carrier signals. Appx5338-40(118:19-120:22). Specifically, he relied on those highlighted in blue below, which he explained are the ones that are, as the preamble specifies, modulated to "encode[] the bit stream." Appx5340(120:14-22).[4] As shown below, the highlighted carriers in the second and subsequent rows carry "message bits" (data).

[4] "[M]odulation" means adjusting the "phase and amplitude" of signals to represent "data bits comprising the transmitted information." Appx255(1:40-55).

Table 12-68 –Bit mapping for R-P-MEDLEY with two bytes per DMT symbol

Plurality of Carrier Signals

Subcarrier index	Constellation point
5, 10, 15, ..., 5 *n*, ...	00
1, 11, 21, ... 10 *n* + 1, ...	SOC message bits 0 and 1
2, 12, 22, ... 10 *n* + 2, ...	SOC message bits 2 and 3
3, 13, 23, ... 10 *n* + 3, ...	SOC message bits 4 and 5
4, 14, 24, ... 10 *n* + 4, ...	SOC message bits 6 and 7
6, 16, 26, ... 10 *n* + 6, ...	SOC message bits 8 and 9
7, 17, 27, ... 10 *n* + 7, ...	SOC message bits 10 and 11
8, 18, 28, ... 10 *n* + 8, ...	SOC message bits 12 and 13
9, 19, 29, ... 10 *n* + 9, ...	SOC message bits 14 and 15
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

Appx12636.

Below, CommScope took the position that there is no infringement because a particular carrier, the DC carrier (sometimes called "carrier 0"), is not phase shifted. In particular, CommScope's counsel invoked the standard's statement that "the sub-carrier with index 0 shall not be rotated." Appx6286(107:11). But that is doubly irrelevant. First, Madisetti identified the relevant plurality of carrier signals that are phase shifted as the ones used to "encode[] the bit stream," which does not include the DC carrier. Appx5340(120:14-22); Appx5388(168:13-17) (identified plurality "[did] not rely on carrier DC carrier 0"). Second, and more important, the DC carrier is irrelevant. The claims address and require phase shifts only for carrier signals "use[d] . . . for modulating [the] bit stream," *i.e.*, data-carrying signals. Appx259(10:58-65). The DC carrier is not modulated to carry data, as the preamble requires. The standard makes clear that the DC carrier—the carrier with

index 0—is not used to modulate the bit stream: In a section titled "Modulation" of "Data subcarriers," it states "the subcarrier with index *i*=0 ***shall not be used***" for data "[t]transmission"; it is not one of the "***data-bearing*** subcarrier[s]." Appx9853 (emphasis added). That a particular carrier signal is not phase-shifted cannot show non-infringement where the claim expressly excludes it—*i.e.*, a carrier that is not used "for . . . modulating a bit stream"—from any phase-shifting requirement.

Indeed, as a matter of basic physics, to speak of "phase-shifting" the DC carrier is incoherent. A "DC" (direct current) signal is an electrical "current" "in which the changes in value are either zero or so small that they may be neglected." *DC Current*, *New IEEE Standard Dictionary of Electrical and Electronics Terms* 355 (5th ed. 1993); *see* Appx5388(168:9-17). Because a DC signal has a constant voltage, not a wave with peaks and valleys, it lacks "phase characteristics" that can be adjusted. A sine wave can be phase shifted on a graph by moving it along the X-axis; but one cannot shift a horizontal line along the X-axis of a graph left or right. No reasonable jury could have found non-infringement by relying on a carrier that TQ Delta's expert did not and could not have identified as being included in the plurality of carriers subject to the claim's phase-shifting requirement.

3. *The Jury Could Not Properly Disregard Madisetti's Testimony*

"[U]nder Fifth Circuit precedent," which applies here, the jury "'[is] not . . . at liberty to disregard arbitrarily the unequivocal, uncontradicted and unimpeached testimony of an expert witness where . . . the testimony bears on technical questions.'" *Imperium IP Holdings (Cayman), Ltd. v. Samsung Elecs. Co., Ltd.*, 757 F. App'x 974, 979 (Fed. Cir. 2019) (quoting *Webster v. Offshore Food Serv., Inc.*, 434 F.2d 1191, 1193 (5th Cir. 1970)) (granting JMOL of invalidity); *Quintana-Ruiz v. Hyundai Motor Corp.*, 303 F.3d 62, 76-77 (1st Cir. 2002) ("a jury verdict cannot be based solely on the jury's rejection of . . . uncontradicted . . . expert testimony on matters outside of lay competence" (citing *Webster*, 303 F.3d at 78)).[5] Here, Madisetti provided unrebutted, unimpeached testimony that the accused devices infringe that the jury was not free to disregard (much less do so on theories foreclosed by the claims and claim construction).

Madisetti addressed each claim limitation, showing both that the standard requires practicing that limitation, and that the accused products practice that limitation (as shown by their source code). Appx5339-52 (119:23-132:15); *see* pp. 13-18, *supra*. The accused devices, moreover, undisputedly practice the standard. Appx5340-52 (120:17-132:15); *see* pp. 31-32, *supra.* The sole countervailing "evidence" consisted of CommScope's lawyer pointing to zero-amount phase

[5] *See NewCSI, Inc. v. Staffing 360 Solutions, Inc.*, 865 F.3d 251, 257 (5th Cir. 2017); *Quinn v. Sw. Wood Prods., Inc.*, 597 F.2d 1018, 1024 (5th Cir. 1979).

shifts in the standard, which Madisetti easily disposed of by explaining that they were simply irrelevant and did "not" "change [his] infringement opinion." Appx5388(168:9-21). The jury was not "at liberty" to disregard that "'unequivocal, uncontradicted and unimpeached'" testimony on highly "'technical questions.'" *Imperium*, 757 F. App'x at 979.

The district court found the jury could have disbelieved Madisetti based on CommScope's "cross-examination." Appx223. But that cross-examination (about non-phase-shifted carriers) was immaterial under the governing claim construction and the claims. *See* pp. 37-45, *supra*. Moreover, cross-examination provided the jury with no basis to question Madisetti's opinion. Madisetti was not "shaken by cross-examination"; he was not "impeached" on any point; and CommScope did not question his "credibility" or qualifications. *Chesapeake & O. Ry. Co. v. Martin*, 283 U.S. 209, 216 (1931). And a jury may not, "under the guise of passing upon the credibility of a witness" simply "disregard his testimony" without basis. *Id.*

This case starkly illustrates the wisdom of the rule that attorney argument cannot overcome expert opinion in technical matters. The first and only time CommScope articulated its non-infringement theory was through its attorney's closing. Appx6286(107:6-19). But his statements were so technically inconsistent as to be unintelligible. Counsel insisted that "the standard" has "four sub-carriers," which he identified as "0, pi over two, pi, or 3 pi over 2." Appx6286(107:12-14).

Those are not subcarriers; they are the four possible phase shifts for the 4,096 subcarriers. Appx9853; Appx10023. Counsel insisted that "the standard says don't shift one" (of those four subcarriers). Appx6286(107:16). But the standard says that each of those modulated subcarriers "shall be . . . ***rotated*** by 0, π/2, π, or 3π/2." Appx10023 (emphasis added). Counsel invoked the statement that the "DC" subcarrier "shall not be rotated." Appx6286(107:11); *see* Appx10023. But the DC subcarrier, a constant voltage, is not a modulated subcarrier (used to transmit data) subject to phase-shifting; it cannot be phase shifted because it is a constant. Appx10023. Had CommScope presented this non-infringement theory through an expert, it would have promptly been excluded, not only as contravening the governing claim construction, *Wiener*, 102 F.3d at 542, but for its myriad errors. Even apart from the fact that attorney argument "is not evidence," *Gemtron Corp. v. Saint-Gobain Corp.*, 572 F.3d 1371, 1380 (Fed. Cir. 2009), such self-contradictory assertions cannot support a non-infringement verdict, *Johns Hopkins Univ. v. Datascope Corp.*, 543 F.3d 1342, 1349 (Fed. Cir. 2008).

II. THE JURY'S INVALIDITY VERDICT FOR THE '835 PATENT RESTS ON AN ERRONEOUS CLAIM CONSTRUCTION AND MUST BE REVERSED

The '835 patent requires transmitting a "flag signal" to synchronize the FIP settings between the sending and receiving modems in high-noise conditions. The patent makes clear that the "flag signal" does not contain data specifying ***when*** the modems should update their FIP settings. Prior art techniques, by contrast,

included such data, which could be corrupted in high-noise conditions. The district court agreed with TQ Delta that the recited "flag" cannot include such timing information, but inexplicably adopted a contrary construction. Appx92. Under the correct construction, JMOL of non-invalidity, or at least a new trial, is required.

A. The Claims and Specification Demonstrate That the Recited "Flag" Cannot Include Data That Addresses Timing

Claim construction begins with the "'claims themselves,'" which are viewed from the perspective of "a person of ordinary skill in the art in question." *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312-13 (Fed. Cir. 2005) (en banc). In the context of computers, a "flag" is a "signal indicating ***the existence*** or status of a particular condition." *Microsoft Dictionary of Computing* 216 (5th ed. 2002) (emphasis added); *see Flag*, *New IEEE Standard Dictionary of Electrical and Electronic Terms* 506 ("variable" that describes a "state," "often 'true or false,'" "or the occurrence of a specified condition"; listing "indication" as a synonym). A "flag" thus is an ***indicator*** that signals the existence of some event or condition without associated ***data or commands***. Applying that ordinary meaning here, a "flag" indicates the condition that the FIP settings need to be updated; it does not contain associated commands directing the other modem ***when*** to update the FIP settings.

The language of asserted claim 10 confirms that plain meaning. Claim 10 requires switching of FIP settings to "occur[] on a ***pre-defined*** forward error

correction codeword boundary following the flag signal." Appx293(21:45-51) (emphasis added). The claim thus requires the timing to be "pre-defined"—*i.e.*, not "defined" by the flag signal itself. Appx293(21:45-46).

The specification—"always highly relevant" and "[u]sually . . . dispositive" to claim construction, *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996)—is equally clear. As the district court observed, the specification shows the invention's purpose is to update FIP settings at a "pre-defined" or "pre-determined" time after the flag signal, instead of having the signal include timing data. Appx92-94. For example, the modems might update the FIP settings "on a ***pre-defined*** FEC codeword boundary following the sync flag"—*i.e.*, after a pre-defined number of codewords (units of data transfer) have been transmitted. Appx288(12:8-12) (emphasis added). Alternatively, they might switch after a "***predetermined number*** of DMT symbols following the transmission of the flag." Appx288(12:25-37) (emphasis added). Figure 6, which depicts an "exemplary method of synchronization using a flag signal," depicts the synchronized switch occurring "***at the predefined change time following the reception of the flag signal***." Appx292(19:14-30) (emphasis added).

The specification expressly contrasts that approach with using "message[s]" that contain data that indicate when to perform the switch, such as after a number of "codeword[s]" specified in the message itself. Appx288(11:10-65). The patent

explains that using a flag is "more desirable" than using data-carrying messages, because it provides "greater impulse noise immunity." Appx288 (11:66-12:7). As TQ Delta's expert Madisetti elaborated, the purpose of switching FIP settings is to deal with noise. Appx4790 (229:1-6). But if the signal to switch is sent in a message containing timing data, that noise can cause corruption of the message; using data-carrying messages thus is "not reliable." Appx1974 (¶¶69-70).

B. The District Court Adopted a Contrary Construction Despite Agreeing the Recited Flag Cannot Include Timing Data

The district court agreed the claimed "flag" cannot include timing information. It recognized that, in the patent, the flag "does not ***itself*** set forth a change time but rather is merely an indication that the updated FIP setting / interleaver parameter value should be used at some juncture that is ***pre-defined*** in relation to when the flag signal is received." Appx93 (emphasis added). It thus found that the claimed flag "is a signal ***to*** change, not a signal of ***when*** to change." Appx92.

The district court, however, refused TQ Delta's proposed construction, under which "flag signal" is an indicator that "does not itself set forth a change time." Appx93-94. Instead, the district court adopted a construction excluding only ***one way*** of specifying the switching time in the message. A "flag" signal, it ruled, excludes only messages that have an "FEC codeword counter value" indicating when to switch FIP settings. Appx93-94. The district court gave no explanation for so narrowing the exclusion. Nor did it attempt to reconcile its holding that

a flag signal "does not itself set forth a change time" with its construction that "flag" encompasses ***all*** signals that "set forth a change time" except those using "FEC codeword counter value[s]" to specify the change. Appx93-94. Nor could it: The district court's construction encompasses myriad signal types that include other data specifying when to change FIP settings, in defiance of its own earlier finding that a flag signal "is a signal ***to*** change, not a signal of ***when*** to change." Appx92.

C. JMOL or a New Trial Is Warranted

The district court's error requires JMOL of non-invalidity, or at the very least a new trial. *See Finisar Corp. v. DirecTV Grp., Inc.*, 523 F.3d 1323, 1333 (Fed. Cir. 2008); *ArcelorMittal France v. AK Steel Corp.*, 700 F.3d 1314, 1325-26 (Fed. Cir. 2012). At trial, CommScope asserted the challenged claim was obvious in view of G.992.1, the DSL standard before VDSL2. Appx5875-77 (320:6-322:14). CommScope's expert acknowledged the "message" he identified as the flag signal in G.992.1 specified "***when***" to switch settings using a "superframe reference number" in the message. Appx5869-70 (314:8-315:4) ("DRA_swap_request message, the flag signal" contains "superframe reference number that's telling me ***when to do the switch***") (emphasis added). He also conceded that a "superframe" is just a larger grouping of "codewords." Appx5866 (311:8-14). Counting superframes is just a variation on counting codewords; either way, the message itself contains data

specifying ***when*** to switch, and that data can be corrupted, which is the very result the invention tries to avoid. Nonetheless, under the district court's construction, CommScope's expert was able to "distinguish between a superframe count and a codeword count" and opine that G.992.1 met the claims. Appx5876(321:3-13). Reversal is required.

III. TQ DELTA IS ENTITLED TO A NEW TRIAL ON DAMAGES

A verdict cannot stand if the jury charge "leaves [the Court] with substantial and ineradicable doubt whether the jury [was] properly guided" and whether "the challenged instructions . . . affected the outcome." *Barry v. Medtronic, Inc.*, 914 F.3d 1310, 1332 (Fed. Cir. 2019) (Fifth Circuit law). That standard is amply met here. Reasonable royalties must be based on the "value of the use of the patented technology." *AstraZeneca AB v. Apotex Corp.*, 782 F.3d 1324, 1344 (Fed. Cir. 2015). Consistent with that, TQ Delta offered evidence that its patented inventions had enormous value: By incorporating them into its products, CommScope was able to offer technology that saved its customers—carriers like AT&T—billions. Using TQ Delta's technology, carriers could and did provide high-speed broadband over existing networks, without replacing over a billion miles of copper wire with fiber to each customer's premises. But the district court restricted the jury to considering "estimated costs . . . that ***CommScope***" itself saved. Appx6238(59:17-22) (emphasis added). That narrow focus defies precedent and rendered TQ

Delta's damages case—which focused on the cost savings to carriers like AT&T—largely irrelevant.

A. This Court's Precedents Require Damages To Reflect the Incremental Value the Patented Invention Adds

Time and again this Court has made clear that "the royalty due for patent infringement should be the value of what was taken—the value of the use of the patented technology." *AstraZeneca*, 782 F.3d at 1344 (quotation marks omitted). The "essential" task is to determine "the incremental value that the patented invention adds." *Ericsson, Inc. v. D-Link Sys., Inc.*, 773 F.3d 1201, 1226 (Fed. Cir. 2014). The question thus is not how much "'the defendant has gained or lost by his unlawful acts.'" *Mentor Graphics Corp. v. EVE-USA, Inc.*, 851 F.3d 1275, 1283 (Fed. Cir. 2017). Patent damages focus on "'customer demand,'" *VirnetX, Inc. v. Cisco Sys., Inc.*, 767 F.3d 1308, 1326 (Fed. Cir. 2014), which determines "'the economic value of the patented technology in the marketplace,'" *Aqua Shield v. Inter Pool Cover Team*, 774 F.3d 766, 771-72 (Fed. Cir. 2014); *see ResQNet.com v. Lansa, Inc.*, 594 F.3d 860, 869 (Fed. Cir. 2010) ("damages" reflect invention's "footprint" in the marketplace).

In *Carnegie Mellon University v. Marvell Technology Group, Ltd.*, 807 F.3d 1283 (Fed. Cir. 2015), for example, the defendant made and sold (but did not use itself) chips for hard drives. *Id.* at 1288-89. This Court upheld a $0.50 per chip royalty for selling chips incorporating the patented technology to create higher-

capacity hard drives. *Id.* That royalty was not just limited to the defendant's own use of the technology. It accounted for the value ***downstream consumers*** placed on devices with the patented features. *Id.* at 1304-05. "[S]trong market pressure," and defendant's "profit goal," showed the defendant would have paid a $.50/unit royalty so it could sell (and its customers could enjoy) the patented technology. *Id.*

That reflects the law. Those who "make" or "sell" infringing goods "value . . . what [they have] taken" based on how much their customers will pay. *AstraZeneca*, 782 F.3d at 1344. The "quantum" of damages "does not depend" on the defendant's position in the supply chain, but on "what royalty reasonably would have resulted from [license] negotiations." *Stickle v. Heublein, Inc.*, 716 F.2d 1550, 1562 (Fed. Cir. 1983); *see Cal. Inst. of Tech. v. Broadcom Ltd.*, 25 F.4th 976, 993-94 (Fed. Cir. 2022). When a patentee negotiates a license with a manufacturer, downstream customers are clearly relevant to the patent's value to the manufacturer; customers' cost savings affect willingness to pay. *See Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1333-34 (Fed. Cir. 2009) ("usage" and "consumer surveys" relevant to hypothetical negotiation). The principle is so settled as to be unremarkable.[6]

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[6] *See, e.g.*, *Summit 6, LLC v. Samsung Elecs. Co.*, 802 F.3d 1283, 1296-98 (Fed. Cir. 2015) (expert properly "valu[ed]" technology based on "data regarding [customer] use"); *Finjan, Inc. v. Secure Computing Corp.*, 626 F.3d 1197, 1211 (Fed. Cir. 2010) (infringer's "'use'" of accused products "encompassed all of their sales" and "advertising value" from the infringing features).

TQ Delta's damages model followed that principle, evaluating reasonable royalties based on the "value of the use of the patented technology." *AstraZeneca*, 782 F.3d at 1344. TQ Delta's expert, Putnam, testified that CommScope's use of the asserted patents afforded CommScope's customers—carriers like AT&T—enormous cost savings. Without that technology, those carriers could offer broadband only by spending billions of dollars to build "extremely expensive" fiber networks. Appx5576(21:17-25); Appx5579-84(24:3-29:20); *see* Appx12710. The patented technology enabled them to offer broadband for far less investment using their existing 1.5 billion miles of copper phone lines. Appx5569-85(14:4-30:23); Appx4748-49(187:12-188:1). Valuing patents by the cost savings they generate is a "well-settled method" for "determin[ing] 'the economic value of the patented technology in the marketplace.'" *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075 (Fed. Cir. 1983); *Aqua Shield*, 774 F.3d at 772. Putnam determined the royalty that would have resulted from a hypothetical negotiation between SEP-holders (including TQ Delta) and implementers (like CommScope), Appx5585-86(30:24-31:13), and apportioned that down to isolate TQ Delta's patented contributions, Appx5593-603(38:19-48:1).

B. The District Court Erroneously Limited TQ Delta to Damages That Reflected Only Cost Savings and Only Cost Savings for One Particular Party

The district court's instructions, however, arbitrarily restricted the jury's focus. They told the jury to consider only the "estimated costs . . . that ***Comm-Scope***" itself saved. Appx6238(59:17-22) (emphasis added). The jury, they directed, should "focus on whether ***Commscope's*** make, use or sale of the patented technology allowed ***it*** to avoid" costs, and if so, "how much ***Commscope*** saved." Appx6238-39(59:23-60:4) (emphasis added). That cannot be reconciled with this Court's precedents. In a hypothetical negotiation with TQ Delta, CommScope would not limit itself to considering only its own cost savings. CommScope would understand the "immense profits" it could realize selling patented technology that allows its phone-carrier customers to save billions. *AstraZeneca*, 782 F.3d at 1334.

CommScope generated $3.4 billion in revenue by taking TQ Delta's DSL technology and selling millions of infringing units to carriers (like AT&T) that were able to save billions of dollars as a result. Appx5576(21:10-25); Appx5570-73(15:22-18:7). A damages award accounting only for ***CommScope's savings*** from using DSL technology—if CommScope used it at all—does not compensate TQ Delta for the value of what CommScope took.

The district court asserted that a contrary instruction was required because TQ Delta's damages evidence used a "cost-savings approach." Appx176. But the

court conceded it could find "no precedent affirmatively holding that the cost-savings approach is limited to the costs savings of the defendant." Appx176. And such a rule would make no sense. Take a patent for a jet engine that uses 50% less fuel than prior-art engines. The "'economic value of the patented technology in the marketplace,'" *Aqua Shield*, 774 F.3d at 771-72, would be based on fuel-cost savings that ***airlines*** could enjoy by equipping their planes with such an engine. Incorporating that technology into jet engines clearly has value: Airlines would pay jet-engine manufacturers far more for such engines. Yet, under the district court's rationale, the royalty in a suit against infringing manufacturers would be zero, because the manufacturers, which do not themselves fly planes, would not themselves enjoy any cost savings. That cannot be correct—it fails to compensate the patent holder for "'the value of what was taken'" when the manufacturer made infringing sales. *AstraZeneca*, 782 F.3d at 1344.

The district court's insistence that its instruction is "grounded in Federal Circuit precedent and legally accurate," Appx176-177, is thus incorrect. The court noted TQ Delta cited authorities where the cost-savings royalty model had "focus[ed] on the cost savings to the defendant," rather than "savings to a non-party." Appx176-77. The cases it discussed—*Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075 (Fed. Cir. 1983), and *Stickle v. Heublein, Inc.*, 716 F.2d 1550 (Fed. Cir. 1983)—happened to be suits against the patented devices' end-users.

Appx176-77. But those cases nowhere suggest that end-users' cost savings cease to be relevant to determining "'the economic value of the patented technology in the marketplace'" where a manufacturer is the defendant and earns billions exploiting the technology to make its products more valuable to its customers. *Aqua Shield*, 774 F.3d at 771-72.

A cost-savings rule that looks only to the defendant's costs would turn this Court's induced-infringement precedents on their head. Here, in addition to infringing directly, CommScope induced its customers' infringement. Appx5259-5261(39:24-41:6)*; see* 35 U.S.C. §§271(a)-(b), 284. As "joint tort-feasors," inducers and direct infringers are each "liable for the full amount of damages . . . suffered by the patentee." *Shockley v. Arcan, Inc.*, 248 F.3d 1349, 1364 (Fed. Cir. 2001). Under the district court's rule, however, the indirect infringer could ***never*** be liable for the value the direct infringer took from the patentee through cost-savings. That defies the rule that indirect infringers like CommScope "proximately cause the full injury to" the plaintiff, 6A Chisum on Patents §20.03[7][b][iv] (Lexis 2024), and are thus liable for "all damages attributable to" their customers' infringing uses, *Water Techs. Corp. v. Calco, Ltd.*, 850 F.2d 660, 669 (Fed. Cir. 1988).

Moreover, under patent-exhaustion principles, "the initial authorized sale of a patented item" may "terminate[] all patent rights to that item." *Quanta*

Computer, Inc. v. LG Elecs., Inc., 553 U.S. 617, 625 (2008); *see Stickle*, 716 F.2d at 1562. The district court's rule would mean that, where an invention saves end-users money, patentees cannot realize their fair share of the invention's full value unless they sue end-users. Not only that, patentees may not even be able to sue end-users; under the "customer-suit" rule, manufacturers can preempt infringement suits against their customers by filing declaratory actions against patentees. *In re Nintendo of Am.*, 756 F.3d 1363, 1365-66 (Fed. Cir. 2014). In that event, district courts "stay" the end-user suits in favor of the manufacturer suit. That would leave patentees in a Catch-22: They must sue end-users to obtain a fair royalty on the invention's full value, but cannot proceed with suits against end users.

C. The Instructions Misstated TQ Delta's Damages Theory

A "party is entitled to a specific instruction on its theory of the case." Wright & Miller, 9C Fed. Prac. & Proc. § 2556 (2024). A court's jury instructions must accurately reflect "how the parties tried the case and their arguments to the jury." *Therasense, Inc. v. Becton, Dickinson & Co.*, 593 F.3d 1325, 1331 (Fed. Cir. 2010). The instructions here plainly misstated the damages theory TQ Delta presented to the jury.

The court told the jury that "TQ Delta . . . has proposed a cost-saving model of calculating reasonable royalty damages" that "relies upon estimated costs . . . ***that CommScope saved*** from making, using, or selling the accused products."

Appx6238 (59:17-22) (emphasis added). That was self-evidently incorrect. The court later acknowledged as much in denying a new damages trial: TQ Delta's "cost-savings model," it noted, "relied on the cost savings ***that AT&T, Comm-Scope's customer, realized*** by using" the patented invention. Appx171 (emphasis added). The court's "inaccurac[y]" in describing TQ Delta's damages theory to the jury "caused the charge as a whole to be so misleading as to compel reversal." *McCullough v. Beech Aircraft Corp.*, 587 F.2d 754, 762 (5th Cir. 1979).

D. TQ Delta's Objection Was Preserved

Under Federal Rule of Civil Procedure 51, parties must make "a proper and timely objection" to jury instructions and "request[ ] alternative instructions that would have remedied the error." *Inline Plastics Corp. v. Lacerta Grp. LLC*, 97 F.4th 889, 898 (Fed. Cir. 2024) (quotation marks omitted); *Kroger Co. v. Roadrunner Transp., Inc.*, 634 F.2d 228, 230 (5th Cir. 1981).

1. Here, both parties proposed reasonable-royalty instructions permitting consideration of cost savings generally (not just CommScope's). *See* Appx6413 (TQ Delta); Appx6412 (CommScope). When the court's instructions nonetheless limited TQ Delta's theory to CommScope's savings, TQ Delta objected. During the formal charge conference, it objected both to the characterization of its damages theory as "rel[ying] upon estimated costs . . . that ***CommScope*** saved" and to the instruction to "focus on whether ***CommScope's*** make, use, or sale of the

patented technology allowed ***it*** to avoid taking a different, more costly course of action." Appx6386 (emphasis added); *see* Appx6189-90(10:14-11:6).

TQ Delta then proposed alternative language—consistent with this Court's precedent—that omitted any limitation on whose cost savings could be considered. Appx6386; *see* Appx6189-90(10:14-11:6). That objection was specific: It proposed surgical alterations to the instruction to omit references to CommScope, and altered the grammar to allow for consideration of carrier cost savings. Appx6189-90(10:14-11:6).[7] That specificity, combined with "previously submitted written requests with citations of authority," was "sufficiently clear to put the judge on notice as to the alleged error in refusing to give the requested charge." *Kroger*, 634 F.2d at 229-30.

TQ Delta's damages theory, moreover, was clear. CommScope emphasized that TQ Delta's damages model was based on carrier cost savings at *Daubert*, in

[7] With TQ Delta's proposed alterations, the instruction would have read:

> TQ Delta, the Plaintiff, has proposed a cost-savings model of calculating reasonable royalty damages that values the Accused Products that CommScope, the Defendant, provides to its customers. This approach relies upon estimated costs, if any, that **~~CommScope saved from~~** **<u>the</u>** making, using, or selling **<u>of</u>** the Accused Products **<u>save</u>**. In considering the amount of reasonable royalty damages under the cost-savings model, you should focus on whether CommScope's **<u>making, using or selling</u>** **~~make, use, or sale~~** of the patented technology **<u>avoided</u>** **~~allowed it to avoid~~** taking a different, more costly course of action, and if so, how much CommScope saved by using the Accused Products instead of taking the more costly course of action.

witness examinations, and even in its Rule 50(a) motion (which was denied). *See* pp. 22-23, *supra*; Appx6178(249:6-11). No one suggested, anywhere, that TQ Delta's damages were based on ***CommScope's*** savings. The court could not have failed to "'underst[an]d [TQ Delta's] position'" when TQ Delta specifically objected to references to CommScope's savings. *Kroger*, 634 F.2d at 230. "When the reason" for an objection "is obvious on its face, little, if anything, need be said." *Curko v. William Spencer & Son, Corp.*, 294 F.2d 410, 412-13 (2d Cir. 1961); *see United States v. Russell*, 134 F.3d 171, 178 n.4 (3d Cir. 1998) (citing *Kroger*, 634 F.2d at 230).

The district court believed "TQ Delta's objection . . . not sufficiently specific because it did not set forth a distinct statement for the grounds for the objection." Appx173. The Fifth Circuit imposes no such rule. *See Kroger*, 634 F.2d at 229-30 (adopting "liberal view" of Rule 51). The grounds need only be apparent. *Id.* And the district court nowhere suggested that it did not ***actually*** understand the basis for TQ Delta's objection. Appx173.

2. Any error was plain regardless. Fed. R. Civ. P. 51(d)(2). Error is "plain" when it is "clear or obvious" and it "'affected the outcome.'" *Puckett v. United States*, 556 U.S. 129, 135 (2009). This Court's precedent is clear that a reasonable royalty must reflect "'the economic value of the patented technology ***in the marketplace***'" for the technology. *Aqua Shield*, 774 F.3d at 771-72 (emphasis

added); *see ResQNet.com*, 594 F.3d at 869. And the "marketplace" plainly encompasses the value assigned by all the customers who purchase and use the accused devices. *See* pp. 54-59, *supra*. Conversely, the district court admitted there was "no precedent" endorsing its rule limiting "the cost saving approach . . . to the cost savings of the defendant" alone. Appx176. The instruction, moreover, was precisely contrary to TQ Delta's theory of the case, and obviously so. Pp. 60-61, *supra*. Nonetheless the court adopted that factually and legally unsupported instruction over both parties' objections. Such "obvious legal error" is the grist of the plain-error rule. *United States v. Suarez*, 879 F.3d 626, 630 (5th Cir. 2018).

The error "seriously affected the trial's fairness." *Wordtech Sys., Inc v. Integrated Networks Sols., Inc.*, 609 F.3d 1308, 1315 (Fed. Cir. 2010). As explained below, it gutted TQ Delta's entire damages theory. *See* pp. 65-67, *infra*. That TQ Delta received ***some*** damages does not mean its "substantial rights" were not "affect[ed]." Fed. R. Civ. P. 51(d)(2). The Patent Act seeks to ensure patent owners "receive full compensation for 'any damages'" from infringement. *Gen. Motors Corp. v. Devex Corp.*, 461 U.S. 648, 654-55 (1983). The district court's instruction potentially resulted in a damages award tens of millions of dollars less than it might otherwise have been—it is nowhere near "full compensation." A new trial is warranted even under plain-error review.

E. The Erroneous Damages Instructions Were Prejudicial

The "prejudicial effect" of the error, *Sulzer*, 358 F.3d at 1363, was manifest. Jury instructions must be considered in "'the context of . . . how the parties tried the case and their arguments to the jury.'" *Therasense*, 593 F.3d at 1331. By telling the jury to focus on CommScope's savings rather than AT&T's, the instruction "virtually destroyed" TQ Delta's damages theory. *McCullough*, 587 F.2d at 762. As the district court acknowledged, TQ Delta's reasonable-royalty model was based on "the cost savings that ***AT&T***, CommScope's customer, realized by using" the patented invention rather than other technologies. Appx171 (emphasis added). On cross-examination, TQ Delta's damages expert, Putnam, agreed that his "entire calculation" of damages was "based on the savings to ***AT&T***." Appx5660(105:14-16) (emphasis added); *see also* Appx5660(105:9-13).

The district court's repeated instruction to consider only what "***CommScope*** saved from making, using, or selling the accused products," Appx6238-39(59:17-60:4) (emphasis added), thus eviscerated TQ Delta's entire damages theory. CommScope made sure that was not lost on the jury. CommScope seized on the erroneous instruction to argue in closing that "[t]he law . . . is what you're supposed to assess is the benefit . . . to the infringer, to CommScope, not to the carrier like AT&T." Appx6292(113:22-24). That CommScope's "closing argument relied on that very" instruction makes the prejudice unavoidable. *United States v.*

Alvarado-Valdez, 521 F.3d 337, 342-43 (5th Cir. 2008). It cannot be said that such an error "'could not have changed the result.'" *Sulzer*, 358 F.3d at 1364. When a "misleading" instruction "tended to withdraw from the notice of the jury" crucial evidence "bearing upon the amount which the plaintiff was entitled to recover," a new trial is warranted. *Hall v. Weare*, 92 U.S. 728, 730-32 (1875).

At minimum, the district court's mischaracterization of TQ Delta's damages theory confused the jury. The jury sat through a trial where TQ Delta presented a damages theory based on ***carrier*** cost savings, *see* pp. 21-23, *supra*, but was then instructed that TQ Delta had relied on ***CommScope's*** cost savings, Appx6238-39(59:17-60:4). The "inaccuracies" in describing TQ Delta's theory independently render the charge "so misleading as to compel reversal." *McCullough*, 587 F.2d at 762.

The district court's assertion that the instruction did not "materially prejudice[ ]" TQ Delta, Appx179-80, cannot be sustained. The court reasoned that the instruction "did not preclude the Jury from considering Dr. Putnam's testimony regarding cost-savings to AT&T" because it did not "bar[ ] consideration of those savings as attributable to CommScope." Appx179. But the instructions told the jury that TQ Delta's damages model "relies upon estimated costs . . . ***CommScope*** saved," and to consider "whether ***CommScope's***"—no one else's—infringement "allowed ***it*** to avoid taking a different, more costly course of action." Appx6238-

39 (59:23-60:4) (emphasis added). The natural reading of the instructions is that the only relevant savings are CommScope's. CommScope so understood the instructions: It told the jury that "[t]he law" required them to "assess . . . the benefit" to "CommScope, ***not to the carrier like AT&T***." Appx6292 (113:22-24) (emphasis added). In "the context of what happened at trial," *Sulzer*, 358 F.3d at 1363, the jury could only have understood that AT&T's cost savings are irrelevant.

The district court's observation that the jury's damages award was "between both TQ Delta and CommScope's proposals," Appx179, hardly shows absence of prejudice. It at most attests to jury confusion—the $11 million figure does not track either party's damages theory, even accounting for the fact that not all patents were found valid and infringed. *See* Appx179 & n.9. The jury, moreover, ruled overwhelmingly for TQ Delta on liability, finding four patents valid and infringed. *See* Appx4549. Yet the jury's $11 million award was less than TQ Delta's proposal for a ***single*** patent and $78 million less than it had requested for all patents. Appx4552. "When damages instructions are faulty and the verdict does not reveal the means by which the jury calculated damages, '[the] error in the charge is difficult, if not impossible, to correct without retrial.'" *Memphis Cmty. Sch. Dist. v. Stachura*, 477 U.S. 299, 312 (1986).

The district court suggested any error was harmless because the result (in its view) was not "inconsistent with substantial justice." Appx179-80. But an "erro-

neous instruction is harmless" under that standard only if it "could not have changed the result." *Sulzer*, 358 F.3d at 1364. Here, the court's instruction clearly could have—and almost certainly did.

CONCLUSION

The district court's judgment on infringement of the '008 patent, invalidity of the '835 patent, and damages should be reversed.

July 19, 2024

Respectfully submitted,

/s/ Jeffrey A. Lamken
Jeffrey A. Lamken
Rayiner Hashem
Jennifer Elizabeth Fischell
MOLOLAMKEN LLP
The Watergate, Suite 500
600 New Hampshire Avenue, N.W.
Washington, D.C. 20037
(202) 556-2000
jlamken@mololamken.com

Catherine Martinez
MOLOLAMKEN LLP
430 Park Avenue
New York, NY 10022
(212) 607-8152

Peter J. McAndrews
Rajendra A. Chiplunkar
David Z. Petty
MCANDREWS, HELD & MALLOY, LTD.
500 West Madison Street, 34th Floor
Chicago, IL 60661
(312) 775-8000
pmcandrews@mcandrews-ip.com

Elizabeth Kathleen Clarke
MOLOLAMKEN LLP
300 North LaSalle Street
Chicago, IL 60654
(312) 450-6704

Counsel for Plaintiff-Appellant TQ Delta, LLC

NONCONFIDENTIAL ADDENDUM

NONCONFIDENTIAL ADDENDUM – TABLE OF CONTENTS

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CONFIDENTIAL MATERIAL OMITTED

On Appx183, Appx197-200, and Appx202-05, information about confidential license agreements has been redacted. On Appx195, a description of sealed evidence has been redacted. On Appx201-02 and Appx205, information about CommScope's sales figures has been redacted. On Appx216, the name of a tool used by CommScope has been redacted. The words "FILED UNDER SEAL" are redacted on the title page of each redacted district court ruling (Appx166, Appx191, and Appx208). That phrase was redacted in the public redacted version filed on the docket below to avoid confusion. For similar reasons, the word "SEALED" is redacted in the CM/ECF header on Appx166-224.

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC, *Plaintiff*, v. COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS US HOLDINGS, INC., ARRIS SOLUTIONS, INC., and ARRIS ENTERPRISES, LLC, *Defendants*.	§ § § § § § § § § § § § §	CIVIL ACTION NO. 2:21-CV-00310-JRG

FINAL JUDGMENT

A jury trial commenced in the above-captioned case on March 17, 2023, and on March 24, 2023, the jury reached and returned its unanimous verdict finding that CommScope Holding Company, Inc., CommScope Inc., Arris International Limited, Arris Global Ltd., Arris US Holdings, Inc., Arris Solutions, Inc., and Arris Enterprises, LLC (collectively, "CommScope" or "Defendants") infringed Claim 17 of U.S. Patent No. 7,453,881 (the "'881 Patent"), Claim 5 of U.S. Patent No. 8,276,048 (the "'048 Patent"), Claim 18 of U.S. Patent No. 8,468,411 (the "'411 Patent"), and Claim 10 of U.S. Patent No. 9,154,354 (the "'354 Patent") (collectively, the "Infringed Claims"); that CommScope did not infringe Claim 14 of U.S. Patent No. 8,090,008 (the "'008 Patent"); that the infringement of the Infringed Claims was willful; that Claim 36 of the '686 Patent and Claim 10 of the '835 Patent are invalid;[1] that Claim 14 of the '008 Patent and Claim 5 of the '048 Patent are not invalid; that the Plaintiff TQ Delta, LLC ("TQ Delta") did not breach its

[1] Though the verdict indicates the jury found these claims to be infringed, their related finding of invalidity is a defense to such infringement and the Court does not consider the infringement of these claims to be operable or compensable. The Court clearly instructed the jury that invalidity is a defense to infringement, and the Court finds their verdict is consistent with the Court's instructions.

contractual duty to grant licenses regarding its Standard Essential Patents to CommScope on fair, reasonable, and non-discriminatory ("FRAND") terms; and that TQ Delta is owed $11,125,000.00 for CommScope's infringement, to be paid in a one-time lump sum for past and future sales. (Dkt. No. 508.)

Pursuant to Rule 58 of the Federal Rules of Civil Procedure, and in accordance with the jury's unanimous verdict and the entirety of the record, the Court hereby **ORDERS** and **ENTERS JUDGMENT** as follows:

1. CommScope infringed Claim 17 of the '881 Patent, Claim 5 of the '048 Patent, Claim 18 of the '411 Patent, and Claim 10 of the '354 Patent;
2. CommScope did not infringe Claim 14 of the '008 Patent;
3. CommScope's infringement of the Infringed Claims was willful;
4. Claim 36 of the '686 Patent and Claim 10 of the '835 Patent are invalid;
5. Claim 14 of the '008 Patent and Claim 5 of the '048 Patent are not invalid;
6. TQ Delta did not breach its contractual duty to grant licenses regarding its Standard Essential Patents to CommScope on FRAND terms;
7. TQ Delta is hereby awarded damages from and against CommScope and shall accordingly have and recover from CommScope the sum of $11,125,000.00 U.S. Dollars as a reasonable royalty for CommScope's infringement, to be paid in a one-time lump sum;
8. Notwithstanding the jury's finding of willfulness, the Court having considered the totality of the circumstances together with the added material benefit of having presided throughout the jury trial and having seen the same evidence and heard the same arguments as the jury, and mindful that enhancement is generally reserved for

"egregious cases of culpable behavior,"[2] concludes that enhancement of the compensatory award herein is not warranted under 35 U.S.C. § 284 and consequently, the Court elects not to enhance the damages awarded herein;

9. Pursuant to 35 U.S.C. § 284 and Supreme Court guidance that "prejudgment interest shall ordinarily be awarded absent some justification for withholding such an award,"[3] the Court awards to TQ Delta from CommScope pre-judgment interest applicable to all sums awarded herein, calculated at the 5-year U.S. Treasury Bill rate, compounded quarterly, from the date of infringement through the date of entry of this Judgment;[4] and

10. Pursuant to 28 U.S.C. § 1961, the Court awards to TQ Delta from CommScope post-judgment interest applicable to all sums awarded herein, at the statutory rate, from the date of entry of this Judgment until paid.

11. Pursuant to Federal Rule of Civil Procedure 54(d), Local Rule CV-54, and 28 U.S.C. § 1920, TQ Delta is the prevailing party in this case and shall recover its costs from CommScope. TQ Delta is directed to file its proposed Bill of Costs.

All other requests for relief now pending and requested by either party but not specifically addressed herein are **DENIED**.

So ORDERED and SIGNED this 3rd day of May, 2023.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

[2] *Halo Electronics, Inc. v. Pulse Electronics, Inc.*, 136 S.Ct. 1923, 1934 (2016).
[3] *General Motors Corp. v. Devex Corp.*, 461 U.S. 648, 657 (1983).
[4] *See Nickson Indus., Inc. v. Rol Mfg. Co., Ltd.*, 847 F.2d 795, 800–801 (Fed. Cir. 1988).

THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC, Plaintiff, v. COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS US HOLDINGS INC., ARRIS SOLUTIONS, INC., ARRIS TECHNOLOGY, INC., and ARRIS ENTERPRISES, LLC, Defendants.	§	CASE NO. 2:21-CV-310-JRG (Lead Case)
TQ DELTA, LLC, Plaintiff, v. NOKIA CORP., NOKIA SOLUTIONS AND NETWORKS OY, and NOKIA OF AMERICA CORP., Defendants.	§	CASE NO. 2:21-CV-309-JRG

CLAIM CONSTRUCTION
MEMORANDUM AND ORDER

Before the Court is the Opening Claim Construction Brief (Dkt. No. 107) filed by Plaintiff TQ Delta, LLC ("Plaintiff" or "TQ Delta"). Also before the Court are the Responsive Claim Construction Brief (Dkt. No. 135) filed by Defendants CommScope Holding Company, Inc., CommScope Inc., ARRIS US Holdings, Inc., ARRIS Solutions, Inc., ARRIS Technology (collectively, "CommScope Defendants"), Nokia of America Corp., Nokia Corp., and Nokia Solutions and Networks Oy (collectively, "Nokia Defendants") (all, collectively, "Defendants"), Plaintiff's reply (Dkt. No. 140), and Defendants' supplemental brief (Dkt. No. 157).

The Court held a hearing on June 1, 2022.

Table of Contents

I. BACKGROUND

Plaintiff submits that "[t]his case generally relates to communications technology for DSL-based systems." (Dkt. No. 124, at 1.)

Plaintiff alleges infringement of United States Patents No. 7,453,881 ("the '881 Patent"), 7,570,686 ("the '686 Patent"), 7,844,882 ("the '882 Patent"), 8,090,008 ("the '008 Patent"), 8,276,048 ("the '048 Patent"), 8,462,835 ("the '835 Patent"), 8,468,411 ("the '411 Patent"), 8,495,473 ("the '5473 Patent"), 8,594,162 ("the '162 Patent"), 8,595,577 ("the '577 Patent"), 8,937,988 ("the '988 Patent"), 9,014,193 ("the '193 Patent"), 9,094,348 ("the '348 Patent"), 9,154,354 ("the '354 Patent"), 9,300,601 ("the '601 Patent"), 9,485,055 ("the '055 Patent"), 9,547,608 ("the '608 Patent"), 9,894,014 ("the '014 Patent"), 10,044,473 ("the '4473 Patent"), 10,409,510 ("the '510 Patent"), 10,567,112 ("the '112 Patent"), and 10,833,809 ("the '809 Patent") (collectively, "the patents-in-suit").

As for the patents that are at issue in these claim construction proceedings, Defendants submit that "the parties refer to the [patent] families by the nomenclature used in the co-pending Delaware Cases that TQ Delta has filed against other defendants: Families 1, 2, 3, 4, 6, 9, and 10," and the parties submit that the disputed terms in these patents have been construed by the District of Delaware, such as in the rulings cited in the following chart:

Name of Group of Patents	Patents	Prior Claim Construction
"Family 1 Patents"	'686 Patent	*TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-CV-01835, Dkt. No. 477 (D. Del. Jan. 30, 2018) (Pl. Ex. 20) (Defs. Ex. 35) ("*Delaware Family 1 CC Opinion*")

"Family 2 Patents"	'881 Patent '193 Patent '601 Patent '014 Patent	*TQ Delta, LLC, v. 2Wire, Inc.*, No. 1:13-CV-01835, Dkt. No. 486 (D. Del. Feb. 7, 2018) (Pl. Ex. 21) (Defs. Ex. 30) ("*Delaware Family 2 CC Opinion*") *TQ Delta, LLC v. 2Wire, Inc.*, 373 F. Supp. 3d 509, 523–24 (D. Del. 2019) ("*Delaware Family 2 SJ Opinion*")
"Family 3 Patents"	'5473 Patent '882 Patent '608 Patent '510 Patent '048 Patent	*TQ Delta, LLC v. 2Wire, Inc.*, 1:13-CV-01835-RGA, et al., Dkt. No. 445 (D. Del. Dec. 18, 2017) (Pl. Ex. 23) ("*Delaware Family 3 CC Opinion*")
"Family 4 Patents"	'008 Patent	*TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-CV-01835, Dkt. No. 473 (D. Del. Jan. 29, 2018) (Pl. Ex. 25) (Defs. Ex. 32) ("*Delaware Family 4 CC Opinion*")
"Family 6 Patents"	'835 Patent '112 Patent '162 Patent	*TQ Delta, LLC, v. 2Wire, Inc.*, No. 1:13-CV-01835, Dkt. No. 447 (D. Del. July 3, 2018) (Defs. Ex. 29) ("*Delaware Family 6 CC Opinion*") *TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-CV-01835, Dkt. No. 540 (D. Del. July 24, 2018) (Defs. Ex. 36) ("*Delaware Family 6 CC Order*") *TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 1377 (D. Del. Mar. 1, 2022). *TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-CV-01835, Dkt. No. 1567 (D. Del. June 28, 2021) ("*Delaware Family 6 SJ Opinion*")
"Family 9 Patents"	'055 Patent '348 Patent '809 Patent '577 Patent '411 Patent '4473 Patent	*TQ Delta, LLC v. Zyxel Commc'ns, Inc.*, No. 1:13-CV-02013, et al., Dkt. No. 521 (D. Del. May 8, 2018) (Pl. Ex. 24) ("*Delaware Family 9 CC Opinion*")

"Family 10 Patents"	'354 Patent '988 Patent	*TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 375 (D. Del. Apr. 27, 2018) (as to related patent)

II. LEGAL PRINCIPLES

It is understood that "[a] claim in a patent provides the metes and bounds of the right which the patent confers on the patentee to exclude others from making, using or selling the protected invention." *Burke, Inc. v. Bruno Indep. Living Aids, Inc.*, 183 F.3d 1334, 1340 (Fed. Cir. 1999). Claim construction is clearly an issue of law for the court to decide. *Markman v. Westview Instruments, Inc.*, 52 F.3d 967, 970–71 (Fed. Cir. 1995) (en banc), *aff'd*, 517 U.S. 370 (1996).

"In some cases, however, the district court will need to look beyond the patent's intrinsic evidence and to consult extrinsic evidence in order to understand, for example, the background science or the meaning of a term in the relevant art during the relevant time period." *Teva Pharm. USA, Inc. v. Sandoz, Inc.*, 135 S. Ct. 831, 841 (2015) (citation omitted). "In cases where those subsidiary facts are in dispute, courts will need to make subsidiary factual findings about that extrinsic evidence. These are the 'evidentiary underpinnings' of claim construction that we discussed in *Markman*, and this subsidiary factfinding must be reviewed for clear error on appeal." *Id.* (citing 517 U.S. 370).

To ascertain the meaning of claims, courts look to three primary sources: the claims, the specification, and the prosecution history. *Markman*, 52 F.3d at 979. The specification must contain a written description of the invention that enables one of ordinary skill in the art to make and use the invention. *Id.* A patent's claims must be read in view of the specification, of which they are a part. *Id.* For claim construction purposes, the description may act as a sort of dictionary, which explains the invention and may define terms used in the claims. *Id.* "One

purpose for examining the specification is to determine if the patentee has limited the scope of the claims." *Watts v. XL Sys., Inc.*, 232 F.3d 877, 882 (Fed. Cir. 2000).

Nonetheless, it is the function of the claims, not the specification, to set forth the limits of the patentee's invention. Otherwise, there would be no need for claims. *SRI Int'l v. Matsushita Elec. Corp.*, 775 F.2d 1107, 1121 (Fed. Cir. 1985) (en banc). The patentee is free to be his own lexicographer, but any special definition given to a word must be clearly set forth in the specification. *Intellicall, Inc. v. Phonometrics, Inc.*, 952 F.2d 1384, 1388 (Fed. Cir. 1992). Although the specification may indicate that certain embodiments are preferred, particular embodiments appearing in the specification will not be read into the claims when the claim language is broader than the embodiments. *Electro Med. Sys., S.A. v. Cooper Life Sciences, Inc.*, 34 F.3d 1048, 1054 (Fed. Cir. 1994).

This Court's claim construction analysis is substantially guided by the Federal Circuit's decision in *Phillips v. AWH Corporation*, 415 F.3d 1303 (Fed. Cir. 2005) (en banc). In *Phillips*, the court set forth several guideposts that courts should follow when construing claims. In particular, the court reiterated that "the claims of a patent define the invention to which the patentee is entitled the right to exclude." *Id.* at 1312 (quoting *Innova/Pure Water, Inc. v. Safari Water Filtration Sys., Inc.*, 381 F.3d 1111, 1115 (Fed. Cir. 2004)). To that end, the words used in a claim are generally given their ordinary and customary meaning. *Id.* The ordinary and customary meaning of a claim term "is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention, i.e., as of the effective filing date of the patent application." *Id.* at 1313. This principle of patent law flows naturally from the recognition that inventors are usually persons who are skilled in the field of the invention and that patents are addressed to, and intended to be read by, others skilled in the particular art. *Id.*

Despite the importance of claim terms, *Phillips* made clear that "the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification." *Id.* Although the claims themselves may provide guidance as to the meaning of particular terms, those terms are part of "a fully integrated written instrument." *Id.* at 1315 (quoting *Markman*, 52 F.3d at 978). Thus, the *Phillips* court emphasized the specification as being the primary basis for construing the claims. *Id.* at 1314–17. As the Supreme Court stated long ago, "in case of doubt or ambiguity it is proper in all cases to refer back to the descriptive portions of the specification to aid in solving the doubt or in ascertaining the true intent and meaning of the language employed in the claims." *Bates v. Coe*, 98 U.S. 31, 38 (1878). In addressing the role of the specification, the *Phillips* court quoted with approval its earlier observations from *Renishaw PLC v. Marposs Societa' per Azioni*, 158 F.3d 1243, 1250 (Fed. Cir. 1998):

> Ultimately, the interpretation to be given a term can only be determined and confirmed with a full understanding of what the inventors actually invented and intended to envelop with the claim. The construction that stays true to the claim language and most naturally aligns with the patent's description of the invention will be, in the end, the correct construction.

Phillips, 415 F.3d at 1316. Consequently, *Phillips* emphasized the important role the specification plays in the claim construction process.

The prosecution history also continues to play an important role in claim interpretation. Like the specification, the prosecution history helps to demonstrate how the inventor and the United States Patent and Trademark Office ("PTO") understood the patent. *Id.* at 1317. Because the file history, however, "represents an ongoing negotiation between the PTO and the applicant," it may lack the clarity of the specification and thus be less useful in claim

construction proceedings. *Id.* Nevertheless, the prosecution history is intrinsic evidence that is relevant to the determination of how the inventor understood the invention and whether the inventor limited the invention during prosecution by narrowing the scope of the claims. *Id.*; *see Microsoft Corp. v. Multi-Tech Sys., Inc.*, 357 F.3d 1340, 1350 (Fed. Cir. 2004) (noting that "a patentee's statements during prosecution, whether relied on by the examiner or not, are relevant to claim interpretation").

Phillips rejected any claim construction approach that sacrificed the intrinsic record in favor of extrinsic evidence, such as dictionary definitions or expert testimony. The *en banc* court condemned the suggestion made by *Texas Digital Systems, Inc. v. Telegenix, Inc.*, 308 F.3d 1193 (Fed. Cir. 2002), that a court should discern the ordinary meaning of the claim terms (through dictionaries or otherwise) before resorting to the specification for certain limited purposes. *Phillips*, 415 F.3d at 1319–24. According to *Phillips*, reliance on dictionary definitions at the expense of the specification had the effect of "focus[ing] the inquiry on the abstract meaning of words rather than on the meaning of claim terms within the context of the patent." *Id.* at 1321. *Phillips* emphasized that the patent system is based on the proposition that the claims cover only the invented subject matter. *Id.*

Phillips does not preclude all uses of dictionaries in claim construction proceedings. Instead, the court assigned dictionaries a role subordinate to the intrinsic record. In doing so, the court emphasized that claim construction issues are not resolved by any magic formula. The court did not impose any particular sequence of steps for a court to follow when it considers disputed claim language. *Id.* at 1323–25. Rather, *Phillips* held that a court must attach the appropriate weight to the intrinsic sources offered in support of a proposed claim construction, bearing in mind the general rule that the claims measure the scope of the patent grant.

The Supreme Court of the United States has "read [35 U.S.C.] § 112, ¶ 2 to require that a patent's claims, viewed in light of the specification and prosecution history, inform those skilled in the art about the scope of the invention with reasonable certainty." *Nautilus, Inc. v. Biosig Instruments, Inc.*, 572 U.S. 898, 910, 134 S. Ct. 2120, 2129 (2014). "A determination of claim indefiniteness is a legal conclusion that is drawn from the court's performance of its duty as the construer of patent claims." *Datamize, LLC v. Plumtree Software, Inc.*, 417 F.3d 1342, 1347 (Fed. Cir. 2005) (citations and internal quotation marks omitted), *abrogated on other grounds by Nautilus*, 572 U.S. 898. "Indefiniteness must be proven by clear and convincing evidence." *Sonix Tech. Co. v. Publ'ns Int'l, Ltd.*, 844 F.3d 1370, 1377 (Fed. Cir. 2017).

"[P]rior orders in related cases do not bar the Court from conducting additional construction in order to refine earlier claim constructions." *TQP Dev., LLC v. Intuit Inc.*, No. 2:12-CV-180-WCB, 2014 WL 2810016, at *6 (E.D. Tex. June 20, 2014) (Bryson, J., sitting by designation).

In general, however, prior claim construction proceedings involving the same patents-in-suit are "entitled to reasoned deference under the broad principals of *stare decisis* and the goals articulated by the Supreme Court in *Markman*, even though *stare decisis* may not be applicable *per se*." *Maurice Mitchell Innovations, LP v. Intel Corp.*, No. 2:04-CV-450, 2006 WL 1751779, at *4 (E.D. Tex. June 21, 2006) (Davis, J.); *see TQP*, 2014 WL 2810016, at *6 ("[P]revious claim constructions in cases involving the same patent are entitled to substantial weight, and the Court has determined that it will not depart from those constructions absent a strong reason for doing so."); *see also Teva*, 135 S. Ct. at 839–40 ("prior cases will sometimes be binding because of issue preclusion and sometimes will serve as persuasive authority") (citation omitted); *Finisar Corp. v. DirecTV Grp., Inc.*, 523 F.3d 1323, 1329 (Fed. Cir. 2008) (noting "the importance of

uniformity in the treatment of a given patent") (quoting *Markman v. Westview Instruments, Inc.*, 517 U.S. 370, 390 (1996)).

III. AGREED TERMS

In their March 14, 2022 P.R. 4-3 Joint Claim Construction and Prehearing Statement, the parties submitted that "[t]he parties do not presently have agreed claim constructions." (Dkt. No. 107, at 2.)

IV. DISPUTED TERMS IN MULTIPLE PATENT FAMILIES

The term numbering used herein corresponds to the numbering used by Plaintiff in Exhibit A to the March 14, 2022 P.R. 4-3 Joint Claim Construction and Prehearing Statement. (Dkt. No. 107, Ex. A.)

1. "transceiver"

"transceiver" '686 Patent, Claims 17, 36, 37 (Family 1) '881 Patent, Claims 17, 18, 23 '193 Patent, Claims 1, 9 '601 Patent, Claims 8, 15 '014 Patent, Claims 1, 3 (Family 2) '882 Patent, Claims 9, 13 '048 Patent, Claims 1, 5 '5473 Patent, Claims 10, 28 '608 Patent, Claim 2 '510 Patent, Claim 22 (Family 3) '835 Patent, Claim 8 '112 Patent, Claims 8, 10 (Family 6) '411 Patent, Claims 10, 18 '577 Patent, Claim 16 '348 Patent, Claims 1, 9 '055 Patent, Claims 11, 17 '809 Patent, Claims 4, 6, 8, 11, 13 (Family 9)	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning, which is: "communications device capable of transmitting and receiving data wherein the transmitter portion and receiver portion share at least some common circuitry."	Plain and ordinary meaning, which is "communications device capable of transmitting and receiving data"

(Dkt. No. 107, Ex. A, at 1–2; *id.*, Ex. B, at 1; Dkt. No. 146, App'x A, at 2; Dkt. No. 149, App'x A, at 2, 4, 9 & 16.)

(a) The Parties' Positions

Plaintiff argues that "[o]ne of ordinary skill in the art would understand that a transceiver shares at least some common circuitry, as the Delaware Court concluded for this term." (Dkt. No. 124, at 2–3.)

Defendants respond that Plaintiff's proposal of requiring "common circuitry" lacks support in the intrinsic record, and Defendants argue that the Delaware construction is not binding and is inconsistent with this Court's construction of "transceiver" in another case. (Dkt. No. 135, at 3.)

Plaintiff replies: "The accepted meaning of 'transceiver'—which refers to a single device that can both transmit and receive—requires that the transmitter and receiver portions share common circuitry, as the Delaware Court found. Otherwise, it would not be a single device." (Dkt. No. 140, at 1.)

At the June 1, 2022 hearing, Plaintiff argued that "transceiver" is a portmanteau of "transmitter" and "receiver" and thus connotes something more specific than merely putting a transmitter and a receiver together. Defendants responded that the transmitter and the receiver within a transceiver *may* share circuitry, but not necessarily.

(b) Analysis

The District of Delaware noted that "[t]he specification does not provide an explicit definition of transceiver," found that "[e]valuating the intrinsic evidence in light of the dictionary definitions provided [by Plaintiff] suggests that a POSA would understand the transmitter and receiver portions to share common circuitry or components," and construed the term "transceiver" in these patents to mean "a communications device capable of transmitting and

receiving data wherein the transmitter portion and receiver portion share at least some common circuitry." *Delaware Family 1 CC Opinion* at 4–5 (citing *Phillips*, 415 F.3d at 1318).

Defendants do not persuasively justify departing from the Delaware construction. In particular, the dictionary definitions of "transceiver" cited by Plaintiff and considered by the District of Delaware are persuasive that a person of ordinary skill in the art would understand the term "transceiver" as referring not merely to a device that includes both a transmitter and a receiver but rather to a device in which a transmitter portion and a receiver portion share at least some common circuitry. (*See id.*; *see also* Dkt. No. 124, at 3; *id.*, Ex. 16, *Merriam Webster Dictionary* 1253 (10th ed. 1998) ("a radio transmitter-receiver that uses many of the same components for both transmission and reception"); *id.*, Ex. 17, *IEEE Standard Dictionary of Electrical and Electronics Terms* 1028 (1988) ("The combination of radio transmitting and receiving equipment in a common housing . . . and employing common circuit components for both transmitting and receiving."); *Delaware Family 1 CC Opinion* at 4; *TQ Delta, LLC v. 2Wire, Inc.*, No. 1:13-CV-01835 (D. Del.), Dkt. No. 342, Aug. 22, 2017 Joint Claim Construction Brief, at 24.) Defendants do not show any error in the consideration of this evidence by the District of Delaware. *See Phillips*, 415 F.3d at 1318 ("Because dictionaries, and especially technical dictionaries, endeavor to collect the accepted meanings of terms used in various fields of science and technology, those resources have been properly recognized as among the many tools that can assist the court in determining the meaning of particular terminology to those of skill in the art of the invention.") (citation omitted).

The specification disclosures cited by Defendants do not compel otherwise, as disclosure of a "transmitter section" and a "receiver section" is not inconsistent with "transceiver" being understood to connote at least some amount of overlap between "sections." (*See* Dkt. No. 135,

at 2–3; *see also* ’686 Patent at 2:1–5 (“Each modem includes a transmitter section for transmitting data and a receiver section for receiving data . . . .”)).) Also, Plaintiff points out that the ’882 Patent appears to contemplate overlap of circuitry, disclosing for example than “an exemplary transceiver could comprise a shared interleaver/deinterleaver memory.” ’882 Patent at 5:33–39.

Finally, Defendants cite this Court’s construction of the term “transceiver” in different patents as meaning “a device that transmits and receives data.” *Wi-LAN Inc. v. HTC Corp.*, No. 2:11-CV-68-JRG, Dkt. No. 302, slip op. at 8 (E.D. Tex. Apr. 11, 2013). That construction was agreed upon by the parties in that case (*see id.*), and Defendants show no indication that those parties had any dispute regarding whether the transmitter portion and receiver portion share at least some common circuitry. Defendants’ reliance on *Wi-LAN* is therefore unpersuasive.

The Court accordingly hereby construes **“transceiver”** to mean **“a communications device capable of transmitting and receiving data wherein the transmitter portion and receiver portion share at least some common circuitry.”**

2. "configurable to," "operable," and "operable to"

"configurable to" "operable" "operable to" '193 Patent, Claims 1, 9 '601 Patent, Claim 8 '014 Patent, Claim 1 (Family 2) '608 Patent, Claim 2 '510 Patent, Claim 22 (Family 3) '112 Patent, Claim 8 (Family 6) '577 Patent, Claim 16 '348 Patent, Claims 1, 9 '055 Patent, Claim 11 (Family 9) '354 Patent, Claim 10 '988 Patent, Claim 16 (Family 10)	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning, which is: "able to be configured" / "capable" / "capable to"	Plain and ordinary meaning, not mere capability

(Dkt. No. 107, Ex. A, at 39–40; *id.*, Ex. B, at 5; Dkt. No. 146, App'x A, at 3; Dkt. No. 149, App'x A, at 24, 27, 28, 29 & 32.)

(a) The Parties' Positions

Plaintiff argues:

> A plain reading of the claims indicates that the "operable to" / "configurable to" terms mean that the claimed transceivers must be capable of performing the recited claim elements. Defendants, through their negative limitation "not mere capability," attempt to read out functionality present in an accused transceiver but

> that may require operation or configuration of the transceiver. For example, in Family 2, bonded transceivers must be connected through wires. A transceiver that contains the capability to be bonded with another transceiver could satisfy the bonding elements although the transceivers are sold individually and are not bonded out of the box.

(Dkt. No. 124, at 4 (citations omitted).)

Defendants respond that the plain and ordinary meaning of "operable to" and "configurable to" does *not* encompass mere capability. (Dkt. No. 135, at 3.) In other words, Defendants argue that "[t]hese terms require structure that presently is 'operable to' or 'configurable to' perform the stated tasks, not merely capable of being *modified* to do so." (*Id.*, at 3–4.) Defendants also submit that their proposal is consistent with rulings by the District of Delaware as well as this Court's prior constructions of "operable to" in other cases. (*Id.*, at 4.)

Plaintiff replies that these terms refer to capabilities and, moreover, *even if* the claims recited "configur*ed* to," the structure need not be in operation in order to infringe because these are not method claims. (Dkt. No. 140, at 1.) Nonetheless, Plaintiff notes that "TQ Delta is also not proposing that the claims encompass mere capability to perform a function in the abstract, such as through re-writing code." (*Id.*, at 2.) Plaintiff urges that "Defendants' 'not mere capability' negative limitation is unhelpful and ambiguous to the jury." (*Id.*)

At the June 1, 2022 hearing, Plaintiff urged that all of these terms relate to capability, not actual operation. In response, Defendants stated that they will not argue that Plaintiff must prove that the accused devices are taken out of their packaging, plugged in, and turned on, but Defendants explained that they are arguing that the functionality must actually be built into the device. Defendants expressed concern that Plaintiff might accuse a functionality that is set forth in an industry standard and that Plaintiff might rely on a hypothetical possibility that such

functionality could have been built into an accused device (even if that functionality is absent in the actual accused device).

(b) Analysis

Claim 1 of the ’193 Patent, for example, recites:

> 1. A device comprising:
> a plurality of transceivers *configurable to* simultaneously operate with a combination of bonded and unbonded transceivers, wherein a first transceiver of the plurality of transceivers is *operable* at a first data rate, and a second transceiver of the plurality of transceivers is simultaneously *operable* at a second data rate that is different than the first data rate, wherein the first and second transceivers are *operable* as bonded transceivers and wherein a third transceiver, of the plurality of transceivers, is simultaneously *operable* at a third data rate and the third transceiver is not bonded with any other transceiver.

As a general matter, the Court of Appeals for the Federal Circuit has noted that “configured to” is narrower than “capable of.” *Aspex Eyewear, Inc. v. Marchon Eyewear, Inc.*, 672 F.3d 1335, 1349 (Fed. Cir. 2012). Also, the District of Delaware discussed “configurable” in the *Delaware Family 2 CC Opinion* at pages 8–11 (in the context of discussing the term “plurality of bonded transceivers”), such as that “‘configurability,’ in the context of the asserted claims, has a narrower meaning than ‘capability.’” The District of Delaware further discussed “configurable to” in the *ADTRAN* case (as to a different patent held by Plaintiff), construing “configured to” and “configurable to” to mean “includes the necessary hardware and software for performing the functionality recited in the claim without the need to rebuild, rewrite or recompile the code for, or redesign any of that hardware or software.” *See TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 1319, slip op. at 8; *see id.* at 7–11 (D. Del. Mar. 30, 2021).

Particularly because the disputed term in the present case is not “configur*ed*” but rather is “configur*able*,” Plaintiff’s proposal of “able to be configured” is appropriate. Of note, in ruling

on motions for summary judgment regarding the ’835 Patent, the District of Delaware cited the *ADTRAN* decision (*id.*) and further stated: “As I explained in that case, ‘configurable to’ does require that the source code required to implement the claimed functionality be present in the invention, but the term does not require that the functionality be enabled in the invention’s initial configuration (i.e., as provided to a consumer).” *Delaware Family 6 SJ Opinion* at 7. The Court’s own prior constructions of “configur*ed* to,” cited here by Defendants, are of limited persuasive value in construing the different term “configurable.” (*See* Dkt. No. 135, at 4.) Also, Plaintiff’s proposal that “configurable” means “able to be configured” is consistent with the meaning of “configurable” in common parlance, and Defendants have not shown that the patentee used “configurable” according to any technical or specialized meaning. *See Phillips,* 415 F.3d at 1314 (“In some cases, the ordinary meaning of claim language as understood by a person of skill in the art may be readily apparent even to lay judges, and claim construction in such cases involves little more than the application of the widely accepted meaning of commonly understood words.”).

In sum, as to the dispute regarding the claim term “configurable to” in the present case, Plaintiff’s proposal of “able to be configured” is sufficiently clear and can be applied in the context of a particular accused device. *See id.*; *see also Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d 1255, 1262 (Fed. Cir. 2013) (“[W]hen a user must activate the functions programmed into a piece of software by selecting those options, the user is only activating the means that are already present in the underlying software.”) (citations and internal quotation marks omitted).

As to the terms “operable” and “operable to,” however, the applicable principle is: “that a device is *capable* of being modified to operate in an infringing manner is not sufficient, by itself, to support a finding of infringement.” *Telemac Cellular Corp. v. Topp Telecom, Inc.*, 247 F.3d

1316, 1330 (Fed. Cir. 2001) (emphasis added). Plaintiff's proposals of "capable" and "capable to" are therefore potentially overbroad because "capable" might be interpreted broadly as allowing for an ability that arises after modification. The *Iron Oak* and *e-Watch* cases cited by Plaintiff did not address this issue. *See Iron Oak Techs., LLC v. Microsoft Corp.*, 857 F. App'x 644, 649 (Fed. Cir. May 24, 2021) (as to a term that recited "operable to create patched operating code . . .," addressing a dispute regarding the timing of the operation); *see also e-Watch Inc. v. Apple, Inc.*, No. 2:13-CV-1061, 2015 WL 1387947, at *6 (E.D. Tex. Mar. 25, 2015) (in addressing dispute regarding whether claims were improper mixed method-apparatus claims, finding that claim language reciting "being operable to" showed that the "patentee understood how to draft claim language that referred to the capabilities of an element"). Indeed, Plaintiff acknowledges that it does not seek an interpretation that would encompass "mere capability to perform a function in the abstract, such as through re-writing code." (Dkt. No. 140, at 2.)

Instead, the terms "operable" and "operable to" should be construed to refer to being *configured* to operate in the recited manner. The District of Delaware reached a similar conclusion in the *ADTRAN* case as to another patent held by Plaintiff. *See TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 909, slip op. at 9 (D. Del. Oct. 31, 2019) ("I find that in view of the relevant cases, 'operable to' requires something more than 'capable of.' I will give 'operable to' its plain and ordinary meaning, which is narrower than 'capable of.'"); *see id.* at 7–9.

As to different claims of the '577 Patent that were at issue in *ADTRAN*, the District of Delaware construed "operable to" to mean "in operation to":

> ADTRAN argues that the claim language "operable to" requires that the multicarrier transceiver actually operates "to receive at least one packet using deinterleaving, and transmit at least one message without using interleaving," and thus, that the claims recite actual operation. I agree.
>
> Thus, I will construe "operable to" to mean "in operation to."

Id., Dkt. No. 800, slip op. at 5–7 (D. Del. Sept. 10, 2019). This decision by the District of Delaware also rejected Plaintiff's argument that "operable to" should be construed to mean "capable of":

> It appears that the claims consistently use the term "operable to" when describing the "multicarrier transceiver" that is part of the claimed apparatus. (*See, e.g.*, '577 patent, cls. 53, 55). In contrast, the claims use "capable of" when defining the apparatus itself, i.e., "The apparatus of claim 53, wherein the apparatus is a linecard that is *capable* of transporting video, voice, and data." (*id.*, cl. 56; *see also, id.*, cls. 19–20, 26–27, 33–34, 40–41, 48–49, 56–57). The claims of the '784 patent do not use the term "capable of." (*See, e.g.*, '784 patent, cl. 7). The difference in usage indicates that the patentee intended for "operable to" and "capable of" to have different meanings. While the apparatus itself needs only to be capable of certain functionalities (transporting video, voice, and data), the transceiver needs to operate in a manner that performs the functions stated in the claim (transmit at least one packet using interleaving, and receive at least one message without using interleaving).

Id. at 6 (footnote omitted). In this context, a fair reading of the District of Delaware's construction of claims in the '577 Patent is that in construing "operable to" to mean "in operation to," the District of Delaware distinguished mere capability and instead required actual configuration to operate in the recited manner. At the June 1, 2022 hearing, Plaintiff argued that the District of Delaware erred by requiring "operation," but when this construction by the District of Delaware is read in the context of the court's analysis distinguishing mere capability, "in operation to" does not appear to require actively operating but rather refers to what occurs when in operation.

That is, "oper*able*" (or "opera*tion*"), at least in the context of the patents here at issue, is *not* tantamount to operat*ing*. At the June 1, 2022 hearing, Defendants stated that they will not

argue that Plaintiff must prove that the accused devices are taken out of their packaging, plugged in, and turned on. The Court finds this interpretation to be appropriate, and this finding is also consistent with decisions of the Federal Circuit. *See, e.g., Finjan, Inc. v. Secure Computing Corp.*, 626 F.3d 1197, 1203–05 (Fed. Cir. 2010) ("it is undisputed that software for performing the claimed functions existed in the products when sold—in the same way that an automobile engine for propulsion exists in a car even when the car is turned off"); *Fantasy Sports Props. v. Sportsline.com, Inc.*, 287 F.3d 1108, 1118 (Fed. Cir. 2002) ("[A]lthough a user must activate the functions programmed into a piece of software by selecting those options, the user is only activating means that are *already present in the underlying software*.").

Any remaining dispute, such as whether or not particular accused transceivers are "operable as bonded transceivers" (*see, e.g.*, '193 Patent, Cl. 1 (reproduced above)), relates to factual issues regarding infringement rather than any legal question for claim construction. *See PPG Indus. v. Guardian Indus. Corp.*, 156 F.3d 1351, 1355 (Fed. Cir. 1998) ("after the court has defined the claim with whatever specificity and precision is warranted by the language of the claim and the evidence bearing on the proper construction, the task of determining whether the construed claim reads on the accused product is for the finder of fact"); *see also Acumed LLC v. Stryker Corp.*, 483 F.3d 800, 806 (Fed. Cir. 2007) ("[t]he resolution of some line-drawing problems . . . is properly left to the trier of fact") (citing *PPG*, 156 F.3d at 1355); *Eon Corp. IP Holdings LLC v. Silver Spring Networks, Inc.*, 815 F.3d 1314, 1318–19 (Fed. Cir. 2016) (citing *PPG*, 156 F.3d at 1355; citing *Acumed*, 483 F.3d at 806).

For example, "when 'a user must activate the functions programmed into a piece of software by selecting those options, the user is only activating the means that are already present in the underlying software.'" *Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d 1255, 1262 (Fed.

Cir. 2013). At the June 1, 2022 hearing, Plaintiff agreed that the scope of this type of activation, in the context of Plaintiff's proposal of "able to be configured," would not include rebuilding source code or redesigning integrated circuit chips. The Court understands this to be merely an illustrative list of examples, so the Court does not include this list in the Court's construction, but the Court expressly relies on these statements by Plaintiff at the June 1, 2022 hearing regarding Plaintiff's understanding of "configured" and "able to be configured."

The Court therefore hereby construes these disputed terms as set forth in the following chart:

Term	**Construction**
"configurable to"	**"able to be configured"**
"operable"	**"configured"**
"operable to"	**"configured to"**

V. DISPUTED TERMS IN THE "FAMILY 1" PATENTS

Plaintiff submits that "[t]he Family 1 Patents relate to communicating certain specified test and/or diagnostic information about the communication channel over which the multicarrier transceiver communicates." (Dkt. No. 124, at 1 (citation omitted).)

The '686 Patent, titled "Systems and Methods for Establishing a Diagnostic Transmission Mode and Communicating Over the Same," issued on August 4, 2009, and bears an earliest priority date of January 7, 2000.

The Abstract of the '686 Patent states:

> Upon detection of a trigger, such as the exceeding of an error threshold or the direction of a user, a diagnostic link system enters a diagnostic information transmission mode. This diagnostic information transmission mode allows for two modems to exchange diagnostic and/or test information that may not otherwise be exchangeable during normal communication. The diagnostic

information transmission mode is initiated by transmitting an initiate diagnostic link mode message to a receiving modem accompanied by a cyclic redundancy check (CRC). The receiving modem determines, based on the CRC, if a robust communications channel is present. If a robust communications channel is present, the two modems can initiate exchange of the diagnostic and/or test information. Otherwise, the transmission power of the transmitting modem is increased and the initiate diagnostic link mode message re-transmitted to the receiving modem until the CRC is determined to be correct.

3. "each bit in the diagnostic message is mapped to at least one DMT symbol," "DMT symbols that are mapped to one bit of the diagnostic message," and "at least one bit in the diagnostic message is mapped to at least one DMT symbol"

"each bit in the diagnostic message is mapped to at least one DMT symbol" '686 Patent, Claim 17	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"each bit in the diagnostic message is communicated using a modulation scheme where a DMT symbol (or two or more DMT symbols) represents only a single bit of the diagnostic message"	Indefinite
"DMT symbols that are mapped to one bit of the diagnostic message" '686 Patent, Claim 36	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"at least one bit in the diagnostic message is communicated using a modulation scheme where two or more DMT symbols represent only the same single bit of the diagnostic message"	Indefinite

"at least one bit in the diagnostic message is mapped to at least one DMT symbol" '686 Patent, Claim 40	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"at least one bit in the diagnostic message is communicated using a modulation scheme where a DMT symbol (or two or more DMT symbols) represents only a single bit of the diagnostic message"	Indefinite

(Dkt. No. 107, Ex. A, at 55; *id.*, Ex. B, at 3; *see* Dkt. No. 146, App'x A, at 3–4; Dkt. No. 149, App'x A, at 34.)

As to "at least one bit in the diagnostic message is mapped to at least one DMT symbol" in Claim 40 of the '686 Patent, this term does not appear in the parties' P.R. 4-5(d) Joint Claim Construction Chart, so Plaintiff evidently no longer asserts the claim in which this term appears. (*See id.*) The Court therefore does not further address this term.

(a) The Parties' Positions

Plaintiff argues that "TQ Delta proposes the construction adopted by the Delaware Court (which also rejected a definiteness challenge)," and "[t]hose in the art understand that 'each bit in the diagnostic message is mapped to at least one DMT symbol' refers to a more robust form of communication utilized in the presence of 'noise' to ensure more reliable communication of the diagnostic message." (Dkt. No. 124, at 5 (citation omitted).) Plaintiff also argues, for example, that "[t]he fact that the claims cover various scenarios or that a mapping function would need to be defined does not render them indefinite." (*Id.*, at 6 (citation omitted).)

Defendants respond that "this language is subject to any number of interpretations, resulting in confusion as to what is intended," and "the specification confirms the ambiguity of the term." (Dkt. No. 135, at 5–6 (citation omitted).) For example, Defendants argue that "the

language of the patent itself raises a number of questions in the mind of a POSITA, such as (1) whether there is some error coding used to map a bit into several redundant symbols, (2) whether the same bit is sent multiple times, once in each symbol, or (3) whether the claim language contemplates something else entirely." (*Id.*, at 6 (citation omitted).)

Plaintiff replies by reiterating that the potential for needing a mapping function does not render these claims indefinite. (Dkt. No. 140, at 2.) Also, Plaintiff submits that it is reasonably clear how one bit could be mapped to more than one symbol because "a single bit could be repeated in the next symbol." (*Id.*, at 3.)

At the June 1, 2022 hearing, in response to inquiry by the Court, Plaintiff stated that construing these terms to have their plain meaning would be sufficient if the Court rejects Defendants' indefiniteness argument.

(b) Analysis

The District of Delaware rejected an indefiniteness challenge as to the term "each bit in the diagnostic message is mapped to at least one DMT signal" in Claim 5 of the '686 Patent and construed the term to mean "each bit in the diagnostic message is mapped to either (1) one signal resulting from DMT modulation or (2) more than one signal resulting from DMT modulation." *Delaware Family 1 CC Opinion* at 14–17.

The specification discloses, for example:

> In the diagnostic link mode, the RT modem sends diagnostic and test information in the form of a collection of information bits to the CO modem that are, for example, modulated by *using one bit per DTM* [*sic*, DMT] *symbol* modulation, as is used in the C-Rates1 message in the ITU and ANSI ADSL standards, where the symbol may or may not include a cyclic prefix. . . .
>
> In the one bit per DMT symbol modulation message encoding scheme, a bit with value 0 is *mapped* to the REVERB1 signal and a bit with a value of 1 *mapped* to a SEGUE1 signal.

’686 Patent at 3:44–57 (emphasis added).

Defendants argue that this disclosure uses “mapped” in relation to a “signal” rather than a “symbol,” but this appears as part of a discussion of modulating bits using “one bit per DMT *symbol* modulation” and thus on its face is relevant to determining whether a person of ordinary skill in the art would understand the word “mapped” in the context of the patent and the terms here at issue. (*Id.* (emphasis added).)

Also, Defendants submit the opinion of their expert that “mapped” is unclear and “could mean that the same bit value is represented by one symbol, two symbols, or every symbol that results from a given DMT signal,” and “[a] person of skill in the art would understand that you have to define a mapping function with specificity in order to implement that particular function.” (Dkt. No. 135, Ex. 23, Mar. 14, 2022 McNair Decl., at ¶ 46.)

On balance, Defendants do *not* persuasively show that a potential need for a “mapping function” renders the claim unclear. Defendants’ expert opines that a person of ordinary skill would not know how to map a bit of data in accordance with these claims (*see id.* at ¶ 50–54), but while this argument perhaps might bear upon the enablement and written description requirements, Defendants’ arguments in this regard do not demonstrate any lack of reasonable certainty as to the scope of these claims.

Defendants thus do not meet their burden to show any lack of reasonable certainty as to the scope of these terms. *See Nautilus*, 572 U.S. at 910; *see also Sonix*, 844 F.3d at 1377. Defendants do not present any alternative proposed constructions. Although Plaintiff has proposed constructions, no further construction is necessary, as Plaintiff agreed at the June 1, 2022 hearing, and indeed the District of Delaware included the word “mapped” in its construction. *Delaware Family 1 CC Opinion* at 14. The Court having rejected Defendants’

indefiniteness argument, and in the absence of any alternative proposed constructions from Defendants, no further construction of these disputed terms is necessary. *See U.S. Surgical Corp. v. Ethicon, Inc.*, 103 F.3d 1554, 1568 (Fed. Cir. 1997) ("Claim construction is a matter of resolution of disputed meanings and technical scope, to clarify and when necessary to explain what the patentee covered by the claims, for use in the determination of infringement. It is not an obligatory exercise in redundancy."); *see also O2 Micro Int'l Ltd. v. Beyond Innovation Tech. Co.*, 521 F.3d 1351, 1362 (Fed. Cir. 2008) ("[D]istrict courts are not (and should not be) required to construe every limitation present in a patent's asserted claims."); *Finjan, Inc. v. Secure Computing Corp.*, 626 F.3d 1197, 1207 (Fed. Cir. 2010) ("Unlike *O2 Micro*, where the court failed to resolve the parties' quarrel, the district court rejected Defendants' construction."); *ActiveVideo Networks, Inc. v. Verizon Commc'ns, Inc.*, 694 F.3d 1312, 1326 (Fed. Cir. 2012); *Summit 6, LLC v. Samsung Elecs. Co., Ltd.*, 802 F.3d 1283, 1291 (Fed. Cir. 2015); *Bayer Healthcare LLC v. Baxalta Inc.*, 989 F.3d 964, 977–79 (Fed. Cir. 2021).

The Court therefore hereby construes **"each bit in the diagnostic message is mapped to at least one DMT symbol"** and **"DMT symbols that are mapped to one bit of the diagnostic message"** to have their **plain meaning**.

4. "array representing frequency domain received idle channel noise information"

"array representing frequency domain received idle channel noise information" '686 Patent, Claims 17, 36	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"ordered set of values representative of noise in the frequency domain that was received by a transceiver on respective subchannels in the absence of a transmission signal on the received channel"	"array of values representative of noise in the frequency domain that was received by a transceiver on respective subchannels in the absence of a transmission signal"

(Dkt. No. 107, Ex. A, at 57; *id.*, Ex. B, at 4; Dkt. No. 146, App'x A, at 3; Dkt. No. 149, App'x A, at 36.)

(a) The Parties' Positions

Plaintiff submits that "TQ Delta's proposed construction is the same construction adopted by the Delaware Court," and Plaintiff argues that "the specification makes clear that a complete absence of any transmission signal is not required." (Dkt. No. 124, at 7 (citation omitted).) As to Plaintiff's proposal that an "array" is an "ordered set of values," Plaintiff submits that "TQ Delta does not understand there to be a substantive dispute regarding the meaning of ['array'], and TQ Delta's plain-meaning construction will help the jury." (*Id.*)

Defendants respond that "'array' is a commonly accepted term of art and need not be further construed," "there is no record support for restricting the claimed 'array' to an 'ordered set' of values as TQ Delta proposes," and "TQ Delta's proposed addition of 'on the received channel' is contrary to the specification." (Dkt. No. 135, at 7 (citation omitted).)

Plaintiff replies that "the claim only requires that one channel is idle—the 'idle channel'—and is silent about what may or may not be transmitting on other channels." (Dkt. No. 140, at 3.) Plaintiff argues that "Defendants' construction improperly narrows the claim (to an impractical or impossible degree) by requiring a complete absence of transmission on *every* channel, not just the channel being measured." (*Id.*)

(b) Analysis

Claim 17 of the '686 Patent, for example, recites (emphasis added):

> 17. An information storage media comprising instructions that when executed communicate diagnostic information over a communication channel using multicarrier modulation comprising:
>
> instructions that when executed direct a transceiver to receive or transmit an initiate diagnostic mode message; and

> instructions that when executed transmit a diagnostic message from the transceiver using multicarrier modulation, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and each bit in the diagnostic message is mapped to at least one DMT symbol, and wherein one variable comprises an *array representing frequency domain received idle channel noise information*.

The District of Delaware construed this disputed term to mean "ordered set of values representative of noise in the frequency domain that was received by a transceiver on respective subchannels in the absence of a transmission signal on the received channel." *Delaware Family 1 CC Opinion* at 7–9.

First, the parties dispute whether the constituent term "array" should be included in the construction or should instead be construed to mean "ordered set of values." The specification uses the word "array" without elaboration. *See* '686 Patent at 4:38–42 ("Many variables that represent the type of diagnostic and test information that are used to analyze the condition of the link are sent from the RT [(remote terminal)] modem to the CO [(central office)] modem. These variables can be, for example, *arrays* with different lengths depending on, for example, information in the initiate diagnostic mode message.") (emphasis added).

The District of Delaware included the phrase "ordered set of values" in its construction of the present term in the '686 Patent, both sides in that case having included that phrase in their proposed constructions. *See Delaware Family 1 CC Opinion* at 7. Plaintiff does not persuasively justify departing from that interpretation of "array" as meaning "ordered set of values," particularly in light of Plaintiff having proposed that phrase in the District of Delaware. *See id.* This will help make clear than an "array" is not merely a collection of information.

As to whether the construction should refer to an absence of a transmission signal "on the received channel," the disputed term itself refers to an "idle channel," which weighs against Defendants' proposal of requiring total absence of *any* transmission signal on *any* channel. The

Background of the Invention section of the specification is consistent with this understanding, referring to a "channel," "subchannels," and also potential "disturbances from other data services":

> The exchange of diagnostic and test information between transceivers in a telecommunications environment is an important part of a telecommunications, such as an ADSL, deployment. In cases where the transceiver connection is not performing as expected, for example, where the data rate is low, where there are many bit errors, or the like, it is necessary to collect diagnostic and test information from the remote transceiver. This is performed by dispatching a technician to the remote site, e.g., a truck roll, which is time consuming and expensive.
>
> In DSL technology, communications over a local subscriber loop between a central office and a subscriber premises is accomplished by modulating the data to be transmitted onto a multiplicity of discrete frequency carriers which are summed together and then transmitted over the subscriber loop. Individually, the carriers form discrete, non-overlapping communication *subchannels* of limited bandwidth. Collectively, the carriers form what is effectively a broadband communications *channel*. At the receiver end, the carriers are demodulated and the data recovered.
>
> DSL systems experience *disturbances from other data services* on adjacent phone lines, such as, for example, ADSL, HDSL, ISDN, T1, or the like. These disturbances may commence after the subject ADSL service is already initiated and, since DSL for internet access is envisioned as an always-on service, the effect of these disturbances must be ameliorated by the subject ADSL transceiver.

'686 Patent at 1:24–49 (emphasis added); *see id.* at 2:4–5 ("the modem transmits data over a multiplicity of subchannels of limited bandwidth").

The District of Delaware noted that the defendants' proposal in that case "allows the interpretation that there is no transmission signal on channels adjacent to the channel being measured," and the District of Delaware rejected the defendants' proposal. *Delaware Family 1 CC Opinion* at 9. Defendants do not persuasively justify departing from this finding by the District of Delaware. In particular, Defendants do not persuasively support their assertion that "for a channel to be idle, as required by the claim, the transceiver must be 'off.'" (Dkt. No. 135,

at 7.) At the June 1, 2022 hearing, Defendants emphasized the disclosure in the specification that refers to interference from "adjacent phone lines." *See* '686 Patent at 1:34–49 (quoted above). Defendants interpret this as meaning that the phrase "idle channel" refers to there being no transmissions on an entire "line," wherein Defendants interpret "line" as referring to physical wires. Defendants' argument is unpersuasive because the disputed term refers to a "channel," not a "line." Likewise, the District of Delaware rejected Plaintiff's proposal that only the *subchannel* on which noise is being measured must be idle. *See Delaware Family 1 CC Opinion* at 8–9. The disputed term refers to a "channel," not a "subchannel."

The Court therefore hereby construes **"array representing frequency domain received idle channel noise information"** to mean **"ordered set of values representative of noise in the frequency domain that was received by a transceiver on respective subchannels in the absence of a transmission signal on the received channel."**

VI. DISPUTED TERMS IN THE "FAMILY 2" PATENTS

Plaintiff submits that "[t]he Family 2 Patents, in general, relate to improvements to a technique known as bonding (which, in the context of DSL, refers to using multiple phone lines to transmit data)." (Dkt. No. 124, at 1 (citation omitted). Of the Family 2 Patents, only the '881 Patent is at issue in the present claim construction proceedings. Defendants submit that "the '881 Patent is asserted against CommScope only" (Dkt. No. 135, at 8 n.6), although Nokia has proposed that "reduce a difference in latency between the bonded transceivers" is indefinite (*see id.*, at 9 n.8).

The '881 Patent, titled "Systems and Methods for Multi-Pair ATM Over DSL," issued on November 18, 2008, and bears an earliest priority date of October 5, 2001. The Abstract of the '881 Patent states:

> At a transmitter, an ATM cell stream is received from the ATM layer and is distributed on a cell-by-cell bases [*sic*] across multiple DSL PHY's. At the receiver, the cells from each DSL PHY are re-combined in the appropriate order to recreate the original ATM cell stream, which is then passed to the ATM layer.

The terms "utilize at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers" and "utilize at least one parameter associated with operation of at least one of the first and second transceivers to reduce a difference in latency between the first and second transceivers" are identified in Defendants' portion of the P.R. 4-3 Joint Claim Construction and Prehearing Statement but not in Plaintiff's portion thereof. *Compare* Dkt. No. 107, Ex. B, at 8 *with id.*, Ex. A. Because Defendants' response brief does not address these terms, the Court concludes that these terms are no longer in dispute, and the Court therefore does not further address these terms.

5. "plurality of bonded transceivers"

"plurality of bonded transceivers" '881 Patent, Claims 17	
Plaintiff's Proposed Construction	**CommScope's Proposed Construction**
"two or more transceivers located on the same side of two or more physical links where each transceiver is configurable to transmit or receive a different portion of the same bit stream via a different one of the physical links"	"two or more transceivers, located on the same side of two or more physical links and each corresponding to one of the physical links, coordinated to transmit or receive a different portion of the same bit stream via a different one of the physical links"

(Dkt. No. 107, Ex. A, at 60; *id.*, Ex. B, at 5; Dkt. No. 146, App'x A, at 3; Dkt. No. 149, App'x A, at 38.)

(a) The Parties' Positions

Plaintiff argues that "the Patents teach that a 'bonded transceiver' is a device that, as a result of hardware and/or software, is configurable to perform bonding (just like a screwdriver is capable of driving a screw)." (Dkt. No. 124, at 8.) Plaintiff also argues that "TQ Delta's proposed construction is the one that the Delaware Court arrived at." (*Id.*) Further, Plaintiff argues that Defendants' proposal "improperly injects a use limitation into a claim written in structural terms." (*Id.* (citation and internal quotation marks omitted).)

CommScope responds that "[u]nlike TQ Delta's proposed construction, CommScope's proposed construction reflects the critical concept that the transceivers must actually do something, *i.e.*, be bonded to transmit different portions of the same bit stream." (Dkt. No. 135, at 9 (citation omitted).) CommScope argues that "[t]he applicants could have chosen language such as a 'plurality of transceivers capable of being bonded,' but they did not," and "TQ Delta should not now be permitted to rewrite the claim." (*Id.*, at 8.)

Plaintiff replies that "Defendants do not provide a reason to depart from the Delaware Court's holding that 'the recited "plurality of bonded transceivers" need not be actively bonding.'" (Dkt. No. 140, at 4 (quoting *Delaware Family 2 CC Opinion* at 11).)

At the June 1, 2022 hearing, the parties submitted that the evidence here is the same as the evidence presented to the District of Delaware on this same disputed term in the same claim. CommScope argued that the District of Delaware erred because the claims do not recite a mere capability or configurability, and CommScope urged that the specification refers to bonding in terms of actual operation.

(b) Analysis

The District of Delaware found:

> The specification's disclosure that [the] system of the invention can be implemented by "physically incorporating" the elements of the claims "into a software and/or hardware system" does not suggest that actual operation of the system would be required to practice the system claims of the invention. In turn, the recited 'plurality of bonded transceivers' need not be actively bonding.

Delaware Family 2 CC Opinion at 11 (citing '881 Patent at 11:31–34); *see id.* at 6–12.

Nonetheless, the District of Delaware also noted:

> Under my construction, a transceiver cannot be a "bonded transceiver" unless it contains the hardware (in the required physical arrangement) and the software necessary for bonding, in such a form that a POSA would not have to rebuild or recode the hardware or software for the transceiver to perform the bonding function. A transceiver may be a "bonded transceiver" if the hardware and software components are present in such a way that a POSA would have to activate them (e.g., by turning the transceiver on) to accomplish the bonding function, but if a POSA would have to modify source code in a transceiver, for example, the transceiver would not qualify as a "bonded transceiver."

Id. at 10 (citing '881 Patent at 16:3–6 & 19:6–19).

Based on this analysis, the District of Delaware construed "plurality of bonded transceivers" to mean "two or more transceivers located on the same side of two or more physical links where each transceiver is configurable to transmit or receive a different portion of the same bit stream via a different one of the physical links, wherein 'configurable to' precludes rebuilding, recoding, or redesigning any of the components in a 'plurality of bonded transceivers.'" *Id.* at 12.

Claim 17 of the '881 Patent, for example, recites (emphasis added):

> 17. A *plurality of bonded transceivers*, each bonded transceiver utilizing at least one transmission parameter value to reduce a difference in latency between the bonded transceivers, wherein a data rate for a first of the bonded transceivers is different than a data rate for a second of the bonded transceivers.

As CommScope points out, the claim does not recite transceivers merely capable of being bonded but rather recites "bonded transceivers." The other claims here at issue are similar in this regard. *See* '881 Patent, Cls. 25, 33 & 37.

The specification, however, uses the term "bonded" in contrast with "traditional" PHYs (wherein "PHYs" refers to "twisted wire pairs," *see* '881 Patent at 1:60–61) and refers to implementing the system in software and/or hardware:

> The exemplary systems and methods of this invention combine multiple DSL PHY's, i.e., multiple twisted wire pairs, to, for example, generate a high data rate connection for the transport of an ATM cell stream between the service provider and, for example, a DSL subscriber.
>
> * * *
>
> In the exemplary system illustrated in FIG. 2, two ADSL PHYs 160 and 170 are "bonded" together to transport a single ATM cell stream. However, it should be appreciated, that the number of ADSL PHYs "bonded" together can be easily expanded to any number (N≥2) of ADSL PHYs thereby, for example, enabling higher ATM data rates. In addition to the two ADSL PHYs 160 and 170 that are bonded together, it should further be appreciated that in some instances in the same access node 100, other ADSL PHYs may be operating in the traditional way. Obviously, the ADSL PHYs operating the traditional way do not need to be connected to the multi-pair multiplexer 140. Thus, in general, it should be appreciated that any combination of "bonded" and unbonded, i.e. traditional, ADSL PHY's, may be configured between the access node 100 and the broadband network determination 200. Furthermore, it should be appreciated that all of the ADSL PHYs can be bonded together.
>
> * * *
>
> The ATM over DSL system can also be implemented by physically incorporating the system and method into a software and/or hardware system, such as the hardware and software systems of a communications transceiver.

'881 Patent at 1:60–64, 4:29–45 & 11:31–34.

This disclosed contrast between "bonded" PHYs and "PHYs operating the traditional way" uses the term "bonded" not to refer to action but rather to refer to a particular type of configuration. The District of Delaware also considered this disclosure, and although the court

found no requirement for "actively bonding" (*Delaware Family 2 CC Opinion* at 11), the court noted that "[t]he specification distinguishes 'bonded' ADSL PHYs from 'unbonded, i.e. traditional' ADSL PHYs based on whether they are actually connected to the multi-pair multiplexer, not whether they are 'configurable' to be in some sort of physical relationship with one another." *Id.* at 8 (citing '881 Patent at 4:34–45). The District of Delaware therefore included the phrase "located on the same side of two or more physical links" in the construction, and the court further clarified that "[t]his suggests that to be 'bonded,' the physical arrangement of a plurality of transceivers must meet certain physical configuration requirements." *Id.*

CommScope's proposed construction in the present case, however, would improperly "inject[] a use limitation into a claim written in structural terms." *Paragon Solutions, LLC v. Timex Corp.*, 566 F.3d 1075, 1090 (Fed. Cir. 2009); *see id.* ("[A]pparatus claims cover what a device is, not what a device does.") (quoting *Hewlett–Packard Co. v. Bausch & Lomb, Inc.*, 909 F.2d 1464, 1468 (Fed. Cir. 1990)). The *Typhoon Touch* case cited by Defendants does not compel requiring active bonding. *See Typhoon Touch Tech. Inc. v. Dell Inc.*, 659 F.3d 1376, 1380–81 (Fed. Cir. 2011) (finding no error where "[t]he district court, in reviewing the specification, held that the 'memory for storing' clause requires that the memory is *actually programmed or configured to* store the data collection application") (emphasis added).

Having reviewed the evidence and arguments presented by the parties in the present case, the Court adopts the above-discussed construction entered by the District of Delaware. Although the phrase "located on the same side of two or more physical links" in that construction requires "physical arrangement" and "physical configuration" of transceivers with regard to one another (*Delaware Family 2 CC Opinion* at 8), the disputed term refers to configuration and does not require active use.

The Court therefore hereby construes **"plurality of bonded transceivers"** to mean **"two or more transceivers located on the same side of two or more physical links where each transceiver is configurable to transmit or receive a different portion of the same bit stream via a different one of the physical links, wherein 'configurable to' precludes rebuilding, recoding, or redesigning any of the components in a 'plurality of bonded transceivers.'"**

6. "reduce a difference in latency between the bonded transceivers"

"reduce a difference in latency between the bonded transceivers" '881 Patent, Claims 17	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"reduce a difference in configuration latency"	Indefinite, or, if not indefinite, "minimize the difference in the configuration latencies between the bonded transceivers"

(Dkt. No. 107, Ex. A, at 61; *id.*, Ex. B, at 6; Dkt. No. 146, App'x A, at 4–5; Dkt. No. 149, App'x A, at 38.)

(a) The Parties' Positions

Plaintiff submits that "[t]he Delaware Court adopted the construction that TQ Delta proposes and rejected Defendants' definiteness attack." (Dkt. No. 124, at 9 (citations omitted).) Plaintiff also argues that "[t]he specification explains that the transmission parameter values determine the configuration latency," "[a]nd the Patents provide examples of how to use transmission parameters to reduce the difference in latency between transceivers." (*Id.*, at 10 (citations omitted).) Further, Plaintiff argues that "the claims do not require comparing actual latency values (or actual data rates)." (*Id.*, at 11.)

CommScope responds that "[t]he specification states that there can be a 'latency difference,' and it describes various types of latencies, but it never explains how to 'reduce a

difference in latency' as the claim requires." (Dkt. No. 135, at 9–10.) As to disclosure in the specification regarding reducing a "configuration latency," CommScope argues that "simply reducing the difference in *configuration latency* is not sufficient to reduce the overall difference in latency *of the system*." (*Id.*, at 10–11.) "Alternatively," CommScope argues, "if this claim term is not indefinite, the Court should adopt CommScope's proposed construction because it is consistent with the specification." (*Id.* at 11.)

Plaintiff replies: "[I]f utilizing the configuration parameters does not reduce a difference in overall latency between transceivers (*e.g.*, due to large hypothetical differences in wire latency), there would be no infringement under Defendants' view of the term. That is not a definiteness issue—when the configuration parameters *did* reduce latency, the claims would be met." (Dkt. No. 140, at 4.) Plaintiff also argues that the constituent term "reduce" does not require minimizing. (*Id.*, at 4–5.)

At the June 1, 2022 hearing, Plaintiff argued that referring to configuration latency is appropriate because, although total system latency includes wire latency, the speed of the signals is so high that any differences in wire latency are insignificant in real-world scenarios. Plaintiff also emphasized that the District of Delaware rejected a proposal to limit "reduce" to meaning "minimize." Defendants responded that the difference in configuration latency needs to be minimized by being set to zero because that is the only interpretation supported by the disclosure in the specification. Defendants also argued that although the specification discusses configuration latency, the specification does not explain what "reduce a difference" means, what the latency was beforehand, or what the latency would have been otherwise.

<u>(b) Analysis</u>

Claim 17 of the '881 Patent, for example, recites (emphasis added):

> 17. A plurality of bonded transceivers, each bonded transceiver utilizing at least one transmission parameter value to *reduce a difference in latency between the bonded transceivers*, wherein a data rate for a first of the bonded transceivers is different than a data rate for a second of the bonded transceivers.

The specification discloses:

> Another effective method of *reducing the difference in latency* between DSL PHYs is mandate that all DSL PHYs are configured with transmission parameters in order to provide the same *configuration latency*. An exemplary method of accomplishing the same configuration latency is by configuring the exact same data rate, coding parameters, interleaving parameters, etc. on all DSL PHYs. Alternatively, different PHYs can have, for example, *different data rates* but use the appropriate coding or interleaving parameters to have the same latency on all the bonded PHYs.

'881 Patent at 6:56–65 (emphasis added).

In the District of Delaware, the parties presented the following proposed constructions for the term "utilizing at least one transmission parameter value to reduce a difference in latency between the bonded transceivers," and the District of Delaware construed the term as follows:

<u>Pl.'s Proposal in Delaware (emphasis added)</u>	<u>Delaware Defs.' Proposal (emphasis added)</u>	<u>Delaware Construction (emphasis added)</u>
"to set a value of at least one parameter used for transmission to *reduce the difference between the latencies* of the respective bonded transceivers"	"configuring at least one transmission parameter value to *minimize the difference in the configuration latencies* between the bonded transceivers"	"utilizing at least one transmission parameter value to *reduce a difference in configuration latency* between the bonded transceivers"

Delaware Family 2 CC Opinion at 16. The District of Delaware thus adopted the defendants' proposal of referring to "configuration" latency. As to the defendants' proposal of "minimize," which Defendants in the present case also propose, the District of Delaware found that "minimize" would be an "unduly narrow limitation" that would improperly limit the claim to a preferred embodiment. *Id.* at 17.

In subsequent proceedings, the District of Delaware rejected an indefiniteness challenge as to this term, finding that the defendants' arguments appeared to be based on the legal standards for written description or enablement rather than indefiniteness. *Delaware Family 2 SJ Opinion*, 373 F. Supp. 3d at 523–524. The District of Delaware also noted that the defendants' expert opined that "'there is no way to establish a reference point to determine that a difference in latency has been reduced'" and that "there is no embodiment demonstrating how to reduce rather than how to eliminate the difference in configuration latency." *Id.* (citations omitted). The District of Delaware found that "[t]he asserted claims are clear on their face as to what is claimed," and "[t]his is not an issue of whether a person of ordinary skill in the art would understand the claim scope, but an issue of whether that claim is properly supported by written description or enabled by the patent specification." *Id.* at 524.

Also of note, the specification discloses "configuration latency . . . is based on the configuration of the DSL transmission parameters . . ." which include "the data rate, coding parameters, such as the coding method, codeword size, interleaving parameters, framing parameters, or the like." '881 Patent at 6:10–15; *see id.* at 6:66–7:34; *see also id.* at 5:7–11 ("The configuration of the multi-pair multiplexing transmitter 300 can be varied to, for example, provide an equal or unequal data rate on the DSL PHYs."); *id.* at 10:40–47 ("a determination is made whether there is a difference in latency between the DSL lines").

These disclosures provide context for understanding "latency" as used in the '881 Patent. In light of these disclosures in the specification, as well as considering the above-discussed claim construction and indefiniteness analysis of the District of Delaware, the indefiniteness opinions of Defendants' expert in the present case are unpersuasive. (*See* Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl., at ¶¶ 61–62.)

The Court adopts the reference to "configuration latency" that was agreed upon and adopted in the District of Delaware. *See Delaware Family 2 CC Opinion* at 16 ("During oral argument, the parties agreed to the Court's proposed construction of this term, except as to how the decrease in configuration latency should be construed.") (footnote omitted). Defendants in the present case point to disclosure in the specification that refers to "end-to-end delay (latency)" as including "configuration latency" as well as "ATM-TC latency," "wire latency" and "design latency." *See* '881 Patent at 6:1–31. These other types of latency, however, do not appear to be relevant to the recital of "reduce a difference in latency between the bonded transceivers." These latencies are disclosed as follows (with reference to "twisted wire pairs," which are referred to as "PHYs" in DSL systems, *see id.* at 1:60–61):

> Th[e] potential latency difference between bonded PHYs places implementation requirements on the multi-pair multiplexer. In particular, the multi-pair multiplexer receiver must be able to reconstruct the ATM stream even if the ATM cells are not being received in the same order as they where [*sic*, were] transmitted.
>
> For example, some of the exemplary reasons for having different delays over different DSL PHYs include, but are not limited, configuration latency which is based on the configuration of the DSL transmission parameters. Specifically, these parameters include the data rate, coding parameters, such as the coding method, codeword size, interleaving parameters, framing parameters, or the like.
>
> ATM-TC latency is based on cell rate decoupling in the ATM-TC. Specifically, the ATM-TC block in ADSL transceivers performs cell rate decoupling by inserting idle cells according to the ITU Standard I.432, incorporated herein by reference in its entirety. This means that depending on the ATU timing and the state of the ATU buffers, an ATM cell that is sent over a DSL PHY will experience non-constant end-to-end delay (latency) through the PHY.
>
> Wire latency is based on differences in the twisted wire pairs. Specifically, the DSL electrical signals can experience different delays based on the difference in length of the wire, the gauge of the wire, the number [of] bridged taps, or the like.
>
> Design latency is based on differences in the DSL PHY design. Specifically, the latency of the PHY can also depend on the design chosen by the manufacture.

> Thus, as result of the different latencies in the PHYs, it is possible that an ATM cell that was sent over a DSL PHY may be received at the multi-pair multiplexing receiver after an ATM cell that was sent out later on a different DSL PHY.

Id. at 6:4–35.

This disclosure supports interpreting the disputed term as referring to configuration latency because what is relevant in the context of the present disputed term is that parameters can be configured. "Wire latency" and "design latency," by contrast, are disclosed as resulting from physical properties of the twisted wire pairs themselves, which are separate from the claimed transceivers. Because the disputed term relates to controlling a difference in latency between the transceivers, a person of ordinary skill in the art would understand that what is being controlled is the configuration of the transceivers, not the physical properties of the physical links. Also, no party has shown that the disclosure of "ATM-TC latency" affects this analysis.

As to Defendants' argument that "a difference in latency" is unclear because the actual latencies cannot be known until the transceivers are in operation, the above-cited disclosures reinforce that the claims can be understood without comparing actual latency values or actual data rates, instead requiring reducing "*a* difference in latency" (such that the difference is less than it would have otherwise been). Also, the claim in which this term appears requires "bonded transceivers," which the Court's construction (above) requires to be "located on the same side of two or more physical links." This requirement of physical links, as part of the claim limitations, provides additional context for a person of ordinary skill in the art to understand reducing a difference in latency between the bonded transceivers.

Further, as to the opinion of Defendants' expert that "it is possible to *increase* the difference in overall latency between two links by *reducing* the difference in configuration latency" (*see* Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl., at ¶ 61), Defendants'

argument in this regard pertains to the hypothetical performance of an implementation rather than to whether the claim language and the construction by the District of Delaware are reasonably clear.

Finally, to whatever extent Defendants are proposing that the claim scope should be limited to the specific embodiment described in above-reproduced column 6, lines 56–65 of the ’881 Patent (*see* Dkt. No. 135, at 11–12), Defendants cite the general proposition that “[c]onsistent use of a term in a particular way in the specification can inform the proper construction of that term.” *See Wi-LAN USA, Inc. v. Apple Inc.*, 830 F.3d 1374, 1382 (Fed. Cir. 2016). The transmission parameters cited by Defendants here, however, appear together with words and phrases such as “[a]n exemplary method” and “for example” (*see* ’881 Patent at 6:56–7:34), and on balance these specific features of a particular disclosed embodiment should not be imported into the claims. *See Phillips*, 415 F.3d at 1323.

The Court therefore hereby construes **“reduce a difference in latency between the bonded transceivers”** to mean **“reduce a difference in configuration latency between the bonded transceivers.”**

7. "each bonded transceiver [utilizing/selecting] at least one transmission parameter value to reduce a difference in latency between the bonded transceivers" and "[utilize/select] at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers"

"each bonded transceiver [utilizing/selecting] at least one transmission parameter value to reduce a difference in latency between the bonded transceivers" '881 Patent, Claims 17, 25	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
(None apart from proposal for the constituent term "reduce a difference in latency between the bonded transceivers")	Indefinite, or, if not indefinite, "each bonded transceiver configured with at least one transmission parameter value to minimize the difference in the configuration latencies between the bonded transceivers"
"[utilize/select] at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers" '881 Patent, Claims 33, 37	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
(None apart from proposal for the constituent term "reduce a difference in latency between the bonded transceivers")	Indefinite, or, if not indefinite, "configure at least one transmission parameter value of each bonded transceiver to minimize the difference in the configuration latencies between the bonded transceivers"

(Dkt. No. 107, Ex. A, at 61; *id.*, Ex. B, at 7–8; *see* Dkt. No. 146, App'x A, at 5; Dkt. No. 149, App'x A, at 39.)

Plaintiff argues these terms together with its arguments as to the constituent term "reduce a difference in latency between the bonded transceivers." (*See* Dkt. No. 124, at 10 n.7.) Defendants present no separate argument as to these terms. (*See* Dkt. No. 135.) At the June 1, 2022 hearing, the parties agreed that these terms present the same issues as discussed above regarding the term "reduce a difference in latency between the bonded transceivers."

Also, the term "[utilize/select] at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers" in Claims 33 and 37 of the '881 Patent does not appear in the parties' P.R. 4-5(d) Joint Claim Construction Chart (*see* Dkt. No. 149, App'x A), so evidently Plaintiff no longer asserts the claims in which that term appears. The Court therefore does not further address that term.

The Court therefore hereby construes **"each bonded transceiver [utilizing/selecting] at least one transmission parameter value to reduce a difference in latency between the bonded transceivers"** to have its **plain meaning** (apart from the Court's construction of the constituent term "reduce a difference in latency between the bonded transceivers," above).

VII. DISPUTED TERMS IN THE "FAMILY 3" PATENTS

Plaintiff submits that "[t]he Family 3 and 9 Patents generally relate to sharing resources, such as sharing memory between an interleaver and deinterleaver or a transmission function and a retransmission function." (Dkt. No. 124, at 1 (citation omitted).)

The '882 Patent, for example, titled "Resource Sharing in a Telecommunications Environment," issued on November 30, 2010, and bears an earliest priority date of October 12, 2004. The Abstract of the '882 Patent states:

> A transceiver is designed to share memory and processing power amongst a plurality of transmitter and/or receiver latency paths, in a communications transceiver that carries or supports multiple applications. For example, the transmitter and/or receiver latency paths of the transceiver can share an interleaver/deinterleaver memory. This allocation can be done based on the data rate, latency, BER, impulse noise protection requirements of the application, data or information being transported over each latency path, or in general any parameter associated with the communications system.

8. "shared memory," "sharing the memory," and "operable to be shared / sharing"

"shared memory" '882 Patent, Claims 9, 13; '048 Patent, Claims 1, 5; '510 Patent, Claims 21, 22 **"sharing the memory"** '5473 Patent, Claim 10 **"operable to be shared / sharing"** '608 Patent, Claim 2	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"shared memory": "common memory used by at least two functions, where a portion of the memory can be used by either one of the functions"	Plain and ordinary meaning

(Dkt. No. 107, Ex. A, at 65; *id.*, Ex. B, at 9; Dkt. No. 146, App'x A, at 5; Dkt. No. 149, App'x A, at 39–40.)

(a) The Parties' Positions

Plaintiff submits that "TQ Delta's proposal matches how the Delaware Court construed this term." (Dkt. No. 124, at 12 (citations omitted).) Plaintiff further submits that the construction by the District of Delaware "aligns with the record" and "[a] Delaware jury rendered a verdict under that construction, and this construction will help the jury here understand this term." (*Id.*) Plaintiff also argues that "[t]he claims recite 'allocating' (or a related word) the shared memory between an interleaver and deinterleaver, which reflects that each allocated portion can be used by either the interleaver or deinterleaver—but not both." (*Id.*, at 13.) Plaintiff urges: "Defendants' plain-and-ordinary meaning construction ignores the context of the intrinsic record—and asserts that any type of memory that could be used by more

than one function at any time, *i.e.*, essentially all memory, is shared memory. But that is not how the Patents use the term, which refers to a common memory allocated between two functions." (*Id.*, at 13–14.)

Defendants respond that "Defendants in this case should not be limited to positions taken by 2Wire" in the District of Delaware, and "TQ Delta's proposed construction improperly narrows the claim language by injecting confusion into a term that was well known to a POSITA at the time of the invention, again without even attempting to support its construction with evidence of disclaimer or lexicography." (Dkt. No. 135, at 12.) Defendants argue that "[n]owhere do the claims require that the same portion of th[e] memory be used by both the interleaver and deinterleaver," and "TQ Delta likewise fails to point to any lexicography or disclaimer in the specification that would limit a POSITA's understanding of a shared memory to this specific implementation." (*Id.*, at 13.)

Plaintiff replies by reiterating that the District of Delaware was correct and that "[t]he plain meaning of a 'shared' resource is that it can be used by multiple things (*e.g.*, a car shared between two people is one that both people can access and drive)." (Dkt. No. 140, at 5.)

At the June 1, 2022 hearing, Plaintiff re-urged that if spaces within a memory structure can only ever be allocated to one function, then that memory structure is not a "shared memory." Defendants responded that the District of Delaware erred by importing a limitation that appears only in some claims, such as Claim 2 of the '608 Patent. Defendants also argued that the construction by the District of Delaware improperly excludes "ping pang" memory (which Defendants submitted is also known as "ping pong" memory).

(b) Analysis

As a threshold matter, the parties have discussed whether certain prior art reference examples of memory can qualify as "shared memory," such as what the parties have referred to as "interprocessor" memory or, as another example, a type of memory known as "ping pang" or "ping pong" memory. These issues pertain to specific invalidity arguments that perhaps may be affected by the Court's claim construction, but the applicability of those prior art references is not presently before the Court. *See Phillips*, 415 F.3d at 1327 ("we have certainly not endorsed a regime in which validity analysis is a regular component of claim construction") (citation omitted).

Turning to the claim language, Claim 9 of the '882 Patent, for example, recites (emphasis added; formatting modified):

> 9. A system that allocates *shared memory* comprising:
>
> a transceiver that performs:
>
> transmitting or receiving a message during initialization specifying a maximum number of bytes of memory that are available to be allocated to an interleaver;
>
> determining an amount of memory required by the interleaver to interleave a first plurality of Reed Solomon (RS) coded data bytes within a *shared memory*;
>
> allocating a first number of bytes of the *shared memory* to the interleaver to interleave the first plurality of Reed Solomon (RS) coded data bytes for transmission at a first data rate, wherein the allocated memory for the interleaver does not exceed the maximum number of bytes specified in the message;
>
> allocating a second number of bytes of the *shared memory* to a deinterleaver to deinterleave a second plurality of RS coded data bytes received at a second data rate; and
>
> interleaving the first plurality of RS coded data bytes within the *shared memory* allocated to the interleaver and deinterleaving the second plurality of RS coded data bytes within the *shared memory* allocated to the deinterleaver, wherein the *shared memory* allocated to

> the interleaver is used at the same time as the *shared memory* allocated to the deinterleaver.

The specification uses the term "share" to refer to a resource being used by multiple "paths." *See, e.g.*, '882 Patent at Abstract ("A transceiver is designed to share memory and processing power amongst a plurality of transmitter and/or receiver latency paths, in a communications transceiver that carries or supports multiple applications.") & 4:59–62 ("The shared memory 120 is shared amongst the two transmitter portion interleavers 216 and 226 and two receiver portion deinterleavers 316 and 326.").

The District of Delaware construed "shared memory" to mean "common memory used by at least two functions, where a portion of the memory can be used by either one of the functions." *Delaware Family 3 CC Opinion* at 5. In that case, the "[d]efendants d[id] not contest that for these patents, at any one time, a certain part of the memory can be used by one function or the other, but not both." *Delaware Family 3 CC Opinion* at 6; *see id.* at 5–7; *see also Delaware Family 9 CC Opinion* at 15 ("Defendants do not contest that for these patents, at any one time, a certain part of the memory can be used by one function or the other, but not both.").

The specification is consistent with finding that a particular portion of a shared memory can be used by only one function at a time:

> [A]n exemplary transceiver can comprise a shared interleaver/deinterleaver memory, such as shared memory 120, and be designed to allocate a first portion of shared memory 120 to a first interleaver, e.g., 216, in the transmitter portion of the transceiver and allocate a second portion of the shared memory to a second interleaver, e.g., 226, in the transmitter portion of the transceiver.

'882 Patent at 5:40–46.

Defendants submit the opinions of their expert that "[w]hether to use the *same location* of memory for multiple functions is a choice that a person of ordinary skill in the art makes about

how to use a shared memory rather than a defining characteristic of a shared memory." (Dkt. No. 135, Ex. 25, Mar. 14, 2022 Wesel Decl., at ¶ 45.) Defendants' expert also opines:

> With random access memories (RAMs), for example, the location where bytes or words of memory are written or read is provided to an address register, and functions are often allocated memory space by assigning to the function a range of addresses. In these circumstances, it might be that multiple functions share the RAM but input addresses into the register and [*sic*] are assigned so that the functions use the memory space without ever using the same portion of memory even though the functionality of the RAM makes it possible and easy for multiple functions to use the same portion of memory. In cases like this, it would be unclear whether, under Plaintiff's construction that requires that "a portion of the memory can be used by either one of the functions," such a memory would meet those requirements.

(*Id.* at ¶ 43; *see id.* at ¶¶ 42–45.)

In reply, Plaintiff urges that Defendants are attempting to read "shared" out of the term "shared memory" by suggesting that different functions could use different memory spaces, thus never using the same portion of the purportedly "shared" memory. (Dkt. No. 140, at 5.) Plaintiff thus appears to argue that, for the "shared memory" limitation to be met, the same *portion* of memory *must* be used by the multiple functions (just not at the same time). (*See id.*)

This apparent position (*id.*) lacks support in the intrinsic evidence and indeed is inconsistent with the claim language reciting "allocating" particular bytes of memory for particular functions *without* reciting *re*allocating the same bytes of memory for different functions. At the June 1, 2022 hearing, Plaintiff clarified that memory can be "shared" without a particular memory space necessarily being used by more than one function over time, so long as the system is configured such that the units of memory within the "shared memory" are each accessible by multiple functions and the relevant source code allows for allocating a unit of memory to different functions over time. The Court agrees, thus finding that "shared memory" does *not* require that the same units of memory must be used by more than one function over

time but *does* require that the system is configured such that each unit of memory can be allocated to different functions over time.

With that understanding, the Court hereby construes these disputed terms as set forth in the following chart:

Term	Construction
"shared memory" **"a memory wherein the memory is operable to be shared"**	**"common memory used by at least two functions, where a portion of the memory can be used by either one of the functions"**
"sharing the memory"	**"using a common memory used by at least two functions, where a portion of the memory can be used by either one of the functions"**

9. "wherein the generated message indicates how the memory has been allocated between the interleaving function and the deinterleaving function"

10. "a message indicating how the shared memory is to be used by the interleaver or deinterleaver"

"wherein the generated message indicates how the memory has been allocated between the interleaving function and the deinterleaving function" '5473 Patent, Claim 28	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Plain and ordinary meaning, i.e., "the message indicates the amount of memory that has been allocated to the [first deinterleaving / interleaving] function and the amount of memory that has been allocated to the [second] deinterleaving function"

"a message indicating how the shared memory is to be used by the interleaver or deinterleaver" '5473 Patent, Claim 10	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Plain and ordinary meaning, i.e., "the message indicates the amount of memory that is to be used by the interleaving function and the amount of memory that is to be used by the deinterleaving function"

(Dkt. No. 107, Ex. A, at 72; *id.*, Ex. B, at 10; Dkt. No. 146, App'x A, at 6; Dkt. No. 149, App'x A, at 46.)[1]

(a) The Parties' Positions

Plaintiff submits: "It is true that the Delaware Court, adopting TQ Delta's proposal, construed one of these terms in the manner Defendants propose here. But the parties in Delaware were addressing a different dispute," and "[t]here was no discussion of the difference, if any, between TQ Delta's proposed construction and the plain meaning of this term." (Dkt. No. 124, at 15 (citation omitted).) "TQ Delta's concern is that Defendants, through the 'amount of memory' language, may resurrect the rejected 'number of bytes' argument before the jury." (*Id.*)

Defendants respond that "[a]s TQ Delta admits, in the Delaware litigation, TQ Delta proposed the construction now put forth by Defendants in this case," and "TQ Delta does not

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[1] Defendants' proposal for these respective terms has been inferred from their amalgamated proposal as to both terms. (*See* Dkt. No. 107, Ex. B, at 10 ("Plain and ordinary meaning, i.e., 'the message indicates the amount of memory [that has been allocated to / is to be used by] the [first deinterleaving / interleaving] function and the amount of memory [that has been allocated to / is to be used by] the [second] deinterleaving function.'"); *see also* Dkt. No. 149, App'x A, at 46–47 (same).)

appear to disagree with this construction, nor can it, given that it is estopped from doing so." (Dkt. No. 135, at 14 (citations omitted; emphasis omitted).) Defendants also argue that Plaintiff's concern regarding the "number of bytes" argument is unfounded but "Defendants agree not to assert that the meaning of this claim language is limited to indicating 'a number of bytes of memory.'" (*Id.*, at 14–15.)

Plaintiff replies that "Defendants do not identify a claim-scope dispute or what their construction excludes that the plain claim language would encompass," and "[g]iven that Defendants now 'agree not to assert that the meaning of this claim language is limited to indicating "a number of bytes of memory,"' there is no need to construe this term." (Dkt. No. 140, at 5–6.)

<u>(b) Analysis</u>

Claim 28 of the '5473 Patent recites (emphasis added):

> 28. An apparatus comprising:
> a multicarrier communications transceiver that is configured to generate a message during an initialization of the transceiver, perform an interleaving function associated with a first latency path, and perform a deinterleaving function associated with a second latency path, the transceiver being associated with a memory,
> wherein at least a portion of the memory may be allocated to the interleaving function or the deinterleaving function at any one particular time and *wherein the generated message indicates how the memory has been allocated between the interleaving function and the deinterleaving function*.

The District of Delaware construed "wherein the generated message indicates how the memory has been allocated between the [first deinterleaving / interleaving] function and the [second] deinterleaving function" to mean "wherein the generated message indicates the amount of memory that has been allocated to the [first deinterleaving / interleaving] function and the amount of memory allocated to the [second] deinterleaving function," which was the construction that Plaintiff proposed in that case. *Delaware Family 3 CC Opinion* at 15. The

court also found, as to the term "amount of memory": "[T]he term is broader than 'bytes,' and the jury will not have trouble deciding what is or is not an 'amount of memory.' Accordingly, I adopt a plain meaning construction. The plain meaning is not limited to bytes, and Defendants cannot argue that it is." *Id.* at 8.

In the present case, whereas Plaintiff expresses concern that "amount of memory" might be misinterpreted as being limited to a number of bytes of memory, Defendants "agree not to assert that the meaning of this claim language is limited to indicating 'a number of bytes of memory.'" (Dkt. No. 135, at 14–15.) Plaintiff therefore does not persuasively justify departing from the Delaware construction, which is the construction that Plaintiff proposed in that case. The Court need not reach Defendants' argument that Plaintiff is estopped from proposing a different construction.

At the June 1, 2022 hearing, Plaintiff argued that its main dispute in the District of Delaware related to the phrase "amount of memory" (which was presented as a disputed term in that case but which does not appear in the claims here at issue). Plaintiff argued that this is why Plaintiff included "amount of memory" in its proposal for the "message" term in that case. Plaintiff's arguments are unpersuasive because the recital of "allocated" connotes an amount, and, again, the Court need resolve any issue of whether Plaintiff is estopped from proposing a different construction. Plaintiff also argued at the June 1, 2022 hearing that memory allocation could be specified as a fraction, a percentage, or as some indication in relation to speed, but Plaintiff did not raise this issue in its briefing and, at least upon the present record, these hypotheticals appear to relate to implementation details that would potentially raise factual issues regarding infringement rather than any legal question for claim construction. *See PPG*, 156 F.3d

at 1355; *see also Acumed*, 483 F.3d at 806 (citing *PPG*); *Eon*, 815 F.3d at 1318–19 (citing *PPG*; citing *Acumed*).

As to the different term "a message indicating how the shared memory is to be used by the interleaver or deinterleaver" in Claim 10 of the '5473 Patent, however, this term does not use the word "allocated." At the June 1, 2022 hearing, Defendants argued that the word "used" is used in the specification in the same way as "allocated," both of which, Defendants argue, refer to an *amount* of memory. On balance, Defendants do not persuasively justify limiting the constituent phrase "how the shared memory is to be used" to indicating amounts of memory for the interleaver and deinterleaver. The opinions of Defendants' expert do not compel the narrowing proposed by Defendants. (*See* Dkt. No. 135, Ex. 25, Mar. 14, 2022 Wesel Decl., at ¶¶ 47–49.) The Court therefore hereby expressly rejects Defendants' proposed construction for the term "a message indicating how the shared memory is to be used by the interleaver or deinterleaver." No further construction of that term is necessary. *See U.S. Surgical*, 103 F.3d at 1568; *see also O2 Micro*, 521 F.3d at 1362; *Finjan*, 626 F.3d at 1207; *ActiveVideo*, 694 F.3d at 1326; *Summit 6*, 802 F.3d at 1291; *Bayer*, 989 F.3d at 977–79.

The Court therefore hereby construes these disputed terms as set forth in the following chart:

Term	Construction
"wherein the generated message indicates how the memory has been allocated between the interleaving function and the deinterleaving function"	**"wherein the generated message indicates the amount of memory that has been allocated to the interleaving function and the amount of memory allocated to the deinterleaving function"**
"a message indicating how the shared memory is to be used by the interleaver or deinterleaver"	**Plain meaning**

11. "specifying a maximum number of bytes of memory that are available to be allocated to [a/an interleaver/deinterleaver]"

"specifying a maximum number of bytes of memory that are available to be allocated to [a/an interleaver/deinterleaver]" '882 Patent, Claims 9, 13 '048 Patent, Claims 1, 5	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Plain and ordinary meaning, where the message must specify a maximum number of bytes.

(Dkt. No. 107, Ex. A, at 72; *id.*, Ex. B, at 10; Dkt. No. 135, at 2; *see* Dkt. No. 146, App'x A, at 6; *see also* Dkt. No. 149, App'x A, at 48.)

(a) Analysis

Plaintiff asserts: "The parties agree 'specifying a maximum number of bytes of memory that are available to be allocated to [a/an interleaver/deinterleaver]' in claims 9 and 13 of the '882 Patent and claims 1 and 5 should be construed as plain-and-ordinary meaning. Dkt. 107-1, at 73 ('Plain and ordinary meaning. No construction necessary.'); Dkt. 107-2, at 10 ('Plain and ordinary meaning')." (Dkt. No. 124, at 2.)

Defendants respond that "while TQ Delta's brief is unclear, TQ Delta's Infringement Contentions indicate that TQ Delta takes a broader position that reads out the requirement—stated directly in the claim term itself—that the message specify the *maximum number of bytes*." (Dkt. No. 135, at 1 (citing '882 Patent at 8:60–9:4).) Defendants propose construing this disputed term as: "plain and ordinary meaning, where the message must specify a maximum number of bytes." (*Id.*, at 2.)

Plaintiff replies: "Defendants' late attempt to construe this term should be rejected. They did not raise any construction in the P.R. 4-3 statement and thus waived the issue. Dkt. 107-2, at 10 ('Plain and ordinary meaning'). Defendants now raise an (incorrect) improper infringe[ment] argument." (Dkt. No. 140, at 6.)

(b) Analysis

Claim 9 of the '882 Patent, for example, recites (emphasis added; formatting modified):

> 9. A system that allocates shared memory comprising:
> a transceiver that performs:
> transmitting or receiving a message during initialization *specifying a maximum number of bytes of memory that are available to be allocated to an interleaver*;
> determining an amount of memory required by the interleaver to interleave a first plurality of Reed Solomon (RS) coded data bytes within a shared memory;
> allocating a first number of bytes of the shared memory to the interleaver to interleave the first plurality of Reed Solomon (RS) coded data bytes for transmission at a first data rate, wherein the allocated memory for the interleaver does not exceed the maximum number of bytes specified in the message;
> allocating a second number of bytes of the shared memory to a deinterleaver to deinterleave a second plurality of RS coded data bytes received at a second data rate; and
> interleaving the first plurality of RS coded data bytes within the shared memory allocated to the interleaver and deinterleaving the second plurality of RS coded data bytes within the shared memory allocated to the deinterleaver, wherein the shared memory allocated to the interleaver is used at the same time as the shared memory allocated to the deinterleaver.

Defendants' proposal of "where the message must specify a maximum number of bytes" simply repeats the language of this claim limitation itself, which already recites (emphasis added): "transmitting or receiving *a message* during initialization *specifying a maximum number of bytes* of memory that are available to be allocated to an interleaver." That is, the claim already

recites that the "message" specifies the maximum number of bytes. The other claims here at issue are the same in this regard. *See* '882 Patent, Cl. 13; *see also* '048 Patent, Cls. 1 & 5. At the June 1, 2022 hearing, Plaintiff agreed that the "message" specifies the maximum number of bytes. The Court therefore hereby expressly rejects Defendants' proposed construction as redundant and as tending to confuse rather than clarify the scope of the claims.

Instead, at least at this stage, Defendants' argument regarding Plaintiff's infringement contentions relates to the sufficiency of Plaintiff's proof on infringement rather than any legal question for claim construction. *See PPG*, 156 F.3d at 1355; *see also Acumed*, 483 F.3d at 806 (citing *PPG*); *Eon*, 815 F.3d at 1318–19 (citing *PPG*; citing *Acumed*). As the Court stated at the June 1, 2022 hearing, the Court fully expects the parties to raise *no later than at the summary judgment stage* any underlying claim construction issue regarding this term that arises because of the particular infringement issues presented in this case.

On that basis, the Court hereby construes **"specifying a maximum number of bytes of memory that are available to be allocated to [a/an interleaver/deinterleaver]"** to have its **plain meaning**.

VIII. DISPUTED TERMS IN THE "FAMILY 4" PATENTS

Plaintiff submits that "[t]he Family 4 Patents generally relate to techniques to reduce the peak-to-average-ratio[] ('PAR') of a carrier signal by scrambling the phase characteristics of the carrier signals." (Dkt. No. 124, at 1 (citation omitted).)

The '008 Patent, titled "System and Method for Scrambling the Phase of the Carriers in a Multicarrier Communications System," issued on January 3, 2012, and bears an earliest priority date of November 9, 1999. The Abstract of the '008 Patent states:

> A system and method that scrambles the phase characteristic of a carrier signal are described. The scrambling of the phase characteristic of each carrier signal

includes associating a value with each carrier signal and computing a phase shift for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal so as to substantially scramble the phase characteristic of the carrier signals. Bits of an input signal are modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced PAR.

12. "phase characteristic(s)"

"phase characteristic(s)" **"each carrier signal has a phase characteristic associated with the bit stream"** '008 Patent, Claim 14	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"one or more values that represent the angular aspect of a carrier signal"	Plain and ordinary meaning

(Dkt. No. 107, Ex. A, at 79; *id.*, Ex. B, at 12; Dkt. No. 146, App'x A, at 6; Dkt. No. 149, App'x A, at 53.)

(a) The Parties' Positions

Plaintiff argues that "TQ Delta's proposed construction is the construction adopted by the Delaware Court," and "Defendants have not articulated a substantive claim scope dispute with respect to TQ Delta's proposed construction." (Dkt. No. 124, at 16.) Plaintiff urges that "TQ Delta's proposed construction tracks the clear teaching of the specification that a phase characteristic of a carrier signal is a value (e.g., the QAM symbol constellation points) that represents the angular aspect of the carrier signal." (*Id.*)

Defendants respond: "[R]ather than provide clarity, TQ Delta's construction simply risks confusing the jury, requiring explanation of QAM symbol constellation points and 'angular aspects of a carrier signal.' Also, TQ Delta's proposal is overly restrictive. Many 'phase

characteristics' may exist for a carrier signal, but TQ Delta's construction limits those characteristics to values that 'represent the angular aspect' of that carrier signal." (Dkt. No. 135, at 15 (citations omitted).)

Plaintiff replies that "QAM encoding will need to be explained to the jury as background of the technology anyway," and "[t]he fact that there may be 'infinite' ways to express phase characteristics says nothing about whether TQ Delta's proposed construction is overly restrictive." (Dkt. No. 140, at 6.)

At the June 1, 2022 hearing, Plaintiff argued that Defendants are opposing Plaintiff's proposed construction because Defendants hope that the jury will be looking for numbers of degrees or radians rather that the digital representations that computers actually use to describe phase characteristics, such as what Plaintiff referred to as an "(X,Y) pair" or an "(I,Q) pair." As to the construction by the District of Delaware, Plaintiff argued that the phrase "a constellation point" would be confusing and so Plaintiff proposes instead referring to "a carrier signal." Defendants responded that this disputed term should be given its plain meaning in the present case because the construction by the District of Delaware was directed to a specific dispute regarding QAM modulation that is not at issue in the present case.

(b) Analysis

Defendants object in their portion of the P.R. 4-3 Joint Claim Construction and Prehearing Statement that Plaintiff's proposed construction is untimely because Plaintiff did not include this term in Plaintiff's P.R. 4-1 disclosures. (Dkt. No. 107, Ex. B, at 12 n.3.) Defendants have not included this objection in their Responsive Claim Construction Brief (*see* Dkt. No. 135), so Defendants evidently no longer assert this objection.

Claim 14 of the '008 Patent recites (emphasis added):

> 14. A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a *phase characteristic* associated with the bit stream, the transceiver capable of:
>
> associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;
>
> computing a phase shift for each carrier signal based on the value associated with that carrier signal; and
>
> combining the phase shift computed for each respective carrier signal with the *phase characteristic* of that carrier signal to substantially scramble the *phase characteristics* of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

The District of Delaware construed "phase characteristics" to mean "one or more values that represent the angular aspect of a constellation point." *See TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 1377 (D. Del. Mar. 1, 2022).

The parties appear to agree that the word "phase," in the context of signal characteristics, is a well-established term of art, and Plaintiff submits its expert's understanding of "constellation points" in this context. (*See, e.g.*, Dkt. No. 124, Ex. 11, Mar. 2022 Madisetti Decl. at ¶¶ 26, 27, 34–36 & 69.) Defendants cite statements by Plaintiff's counsel during a claim construction hearing in the District of Delaware that "there are numerous ways that one skilled in the art would understand that a phase characteristic can be expressed" and that there could be "infinite" phase characteristics. (*See* Dkt. No. 135, Ex. 34, Mar. 18, 2021 Hr'g Tr. at 19 & 25.) Defendants have not identified any contradiction between those cited statements and the construction proposed by Plaintiff in the present case. For example, Plaintiff's statements regarding "infinite" phase characteristics, when read in context, can be understood as stating that a particular phase characteristic may have an infinite number of possible values. (*See id.* at 19.)

Nonetheless, Plaintiff does not persuasively support its proposal of modifying the District of Delaware construction so as to refer to an "angular aspect of a carrier signal" rather than an

"angular aspect of a constellation point." At the June 1, 2022 hearing, Plaintiff attempted to explain its divergence from the construction of the District of Delaware, but the transcript of the proceeding in the District of Delaware reflects that the court relied upon Plaintiff's acceptance of the phrase "constellation point" in that case and found that "constellation point" more precisely tethered the construction to modulation than did Plaintiff's proposal of "carrier signal." *See TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 1388, Mar. 1, 2022 Tr. at 119:1–8 (discussing Plaintiff's expert's proposal of "one or more values that represent the angular aspect of the carrier signal"); *see also id.* at 141:17–23. That transcript also reflects a general impression that the District of Delaware "do[es]n't really think that there's much of a dispute between [the experts, and] I think the disputes here more go to, I assume, infringement, possibly invalidity, and they are a matter for a different kind of hearing than claim construction." *Id.* at 143:9–13. Finally, the declaration of Plaintiff's expert in the present case reflects an understanding of "constellation points" in the relevant context. (*See, e.g.,* Dkt. No. 124, Ex. 11, Mar. 2022 Madisetti Decl. at ¶¶ 34–36.)

Based on all of the foregoing, the Court hereby construes **"phase characteristic(s)"** to mean **"one or more values that represent the angular aspect of a constellation point."**

13. "substantially scramble the phase characteristics of the plurality of carrier signals"

"substantially scramble the phase characteristics of the plurality of carrier signals" '008 Patent, Claim 14	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"adjust the phase characteristics of the carrier signals by varying amounts to produce a transmission signal with a reduced peak[-]to-average power ratio (PAR)"	Plain and ordinary meaning

(Dkt. No. 107, Ex. A, at 80; *id.*, Ex. B, at 11; Dkt. No. 146, App'x A, at 7; Dkt. No. 149, App'x A, at 54.)

(a) The Parties' Positions

Plaintiff argues that "TQ Delt[a] proposes the construction of this term adopted by the Delaware Court," and "Defendants have not raised a substantive dispute with that construction." (Dkt. No. 124, at 17.) Plaintiff also cites disclosures in the specification for support. (*Id.*)

Defendants respond that "TQ Delta's construction should be rejected in favor of the plain and ordinary meaning," and "[i]t is well established that importing functional language from the specification into a term's construction is inappropriate." (Dkt. No. 135, at 16 (citations omitted).)

Plaintiff replies that "[c]laiming a functional result is not per se improper," and "TQ Delta's proposed construction simply defines what that claimed result—'to substantially scramble'—means." (Dkt. No. 140, at 7.)

(b) Analysis

Claim 14 of the '008 Patent recites (emphasis added):

> 14. A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:
>
> associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;
>
> computing a phase shift for each carrier signal based on the value associated with that carrier signal; and
>
> combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to *substantially scramble the phase characteristics of the plurality of carrier signals*, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

The District of Delaware construed this disputed term to mean "adjust the phase characteristics of the carrier signals by varying amounts to produce a transmission signal with a reduced peak-to-average power ratio (PAR)." *Delaware Family 4 CC Opinion* at 6. In doing so, the District of Delaware rejected an indefiniteness challenge (based on the word "substantially"), finding that "[i]n light of the supplemental declaration of Plaintiffs expert, Dr. Cooklev, I am persuaded that a person of ordinary skill in the art would understand how much scrambling one would perform to 'substantially scramble,' that is, to scramble the phase characteristics with the object of reducing PAR." *Id.* at 7. The District of Delaware thus adopted Plaintiff's proposal of the phrase "to produce a transmission signal with a reduced peak-to-average power ratio (PAR)." *See id.* at 6–8. Plaintiff proposes the Delaware construction in the present case.

Plaintiff also cites disclosure in the specification that scrambling the phase characteristics of carrier signals "produce[s] a transmission signal with a reduced PAR," wherein "PAR" refers to peak-to-average power ratio. '008 Patent at Abstract; *see id.* at 1:26–29 ("[T]he invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals."); *see also id.* at 2:44–47 ("[T]he input bit stream is modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced peak-to-average power ratio (PAR)."); *id.* at 6:49–53 ("By scrambling the phase characteristics of the carrier signals, the phase scrambler 66 reduces (with respect to unscrambled phase characteristics) the combined PAR of the plurality of carrier signals and, consequently, the transmission signal 38.").

Defendants argue that the Delaware construction improperly imported functional language from the specification, and that "TQ Delta provides no argument regarding disclaimer, disavowal, or lexicography to support its construction." (Dkt. No. 135, at 16.) Defendants cite,

for example, the proposition that: "[T]he fact that the claimed composition was designed to solve certain problems of the prior art and the fact that the patentee noted the functional import of having a [particular feature] does not mean that we must attribute a function to [a] nonfunctional phrase . . . . Where the function is not recited in the claim itself by the patentee, we do not import such a limitation." *Ecolab, Inc. v. Envirochem, Inc.*, 264 F.3d 1358, 1367 (Fed. Cir. 2001) (citation omitted).

Defendants' argument is unpersuasive because the claim itself recites the disputed term as "combining . . . to substantially scramble . . .," so this limitation *is* expressly recited in functional terms, and the construction by the District of Delaware clarifies the nature of this recited functionality. *See id.* The District of Delaware considered specification disclosures as well as expert opinion and reached a conclusion regarding how a person of ordinary skill in the art would understand the "substantially scrambled" term, particularly given that "the specifications indicate that, at a minimum, the goal is to reduce PAR." *Delaware Family 4 CC Opinion* at 8. The District of Delaware cited disclosures in United States Patent No. 7,292,627, and the '088 Patent here at issue is a descendent of the '627 Patent (related through a series of continuation patent applications). *Id.* (citing '627 Patent at 1:19–22, 2:41–45 & 6:55–59). Defendants do not persuasively justify departing from the construction reached by the District of Delaware.

At the June 1, 2022 hearing, Defendants cited a dependent claim of the ancestor '627 Patent that recites "modulating bits of the input bit stream onto the carrier signals having the substantially scrambled phase characteristics to produce a transmission signal with a reduced peak-to-average power ratio (PAR)." '627 Patent, Cl. 2. Defendants' argument is, or is akin to, a claim differentiation argument, but the doctrine of claim differentiation is "a guide, not a rigid

rule." *Wi-LAN USA, Inc. v. Apple Inc.*, 830 F.3d 1374, 1391 (Fed. Cir. 2016) (citation and internal quotation marks omitted); *see Multilayer Stretch Cling Film Holdings, Inc. v. Berry Plastics Corp.*, 831 F.3d 1350, 1360 (Fed. Cir. 2016) ("The dependent claim tail cannot wag the independent claim dog."); *see also N. Am. Vaccine, Inc. v. Am. Cyanamid Co.*, 7 F.3d 1571, 1577 (Fed. Cir. 1993) (same).

Also, whereas dependent Claim 2 of the '627 Patent *adds* a limitation of "modulating bits of the input stream onto the carrier signals," the claim here at issue (Claim 14 of the '008 Patent, reproduced above) already recites that the scrambled carrier signals are used to modulate. The absence of a modulating step in independent Claim 1 of the '627 Patent perhaps explains why a reference to peak-to-average power ratio is added in a dependent claim (together with a step of modulating). Thus, whereas a modulation requirement accompanies the disputed language in dependent Claim 2 of the '627 Patent, a modulation requirement is already present in Claim 14 of the '008 Patent. Dependent Claim 2 of the '627 Patent therefore does *not* weigh against construing Claim 14 with reference to peak-to-average power ratio.

The Court accordingly hereby construes **"substantially scramble the phase characteristics of the plurality of carrier signals"** to mean **"adjust the phase characteristics of the carrier signals by varying amounts to produce a transmission signal with a reduced peak-to-average power ratio (PAR)."**

14. "same bit value"

15. "multiple carrier signals corresponding to the scrambled carrier signals are used by the first multicarrier transceiver to modulate the same bit value"

"same bit value" '008 Patent, Claim 14	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"value of the same bit"	Indefinite
"multiple carrier signals corresponding to the scrambled carrier signals are used by the first multicarrier transceiver to modulate the same bit value" '008 Patent, Claim 14	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"a first carrier signal is used by the first multicarrier transceiver to ~~de~~modulate the value of a bit ~~of the received bit stream~~ and at least one more carrier signal is used by the first multicarrier transceiver to ~~de~~modulate the value of the same bit ~~of the received bit stream~~, wherein the carrier signals correspond to the plurality of phase-shifted and scrambled carrier signals"[2]	Indefinite

(Dkt. No. 107, Ex. A, at 80–82; *id.*, Ex. B, at 11; Dkt. No. 146, App'x A, at 7; Dkt. No. 149, App'x A, at 55.)

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[2] Deletions by Plaintiff's counsel during the June 1, 2022 hearing are shown in strikeout. Plaintiff also previously proposed: "a first carrier signal is used by the first multicarrier transceiver to *modulate* the value of a bit of the received bit stream and at least one more carrier signal is used by the first multi carrier transceiver to *modulate* the value of the same bit of the received bit stream, wherein the carrier signals correspond to the plurality of phase-shifted and scrambled carrier signals." (Dkt. No. 107, Ex. A, at 81–82 (emphasis added).)

(a) The Parties' Positions

Plaintiff argues that whereas "Defendants argue that the 'same bit value' could refer to either the bit position or the value of the bit," "the specification, as Defendants recognize, explains that the 'bit value' refers to the data carried by a carrier signal." (Dkt. No. 124, at 18 (citations omitted).)

Defendants respond: "Both of these terms refer to the 'same bit value,' which is indefinite because a POSITA would not understand with reasonable certainty whether 'same bit value' refers to the same bit position or instead refers to the same bit value as between 0's and 1's. As discussed below, TQ Delta itself has taken inconsistent positions regarding this term, demonstrating that the term is indefinite: TQ Delta adopted the former construction (same bit position) in Delaware, but now proposes a different construction (value of the same bit)." (Dkt. No. 135, at 17 (citation omitted).) Defendants also argue that "different meanings used in the specification create uncertainty over claim scope, and the prosecution history does not provide any guidance either." (*Id.*, at 18 (citation omitted).)

Plaintiff replies that "Defendants contrive an indefiniteness argument based on a false dichotomy that the Patent discloses two different concepts: 1) 'same input data bits' (or 'input data bit') which Defendants' contend means the bit position in a data stream, and 2) 'bit value' which refers to the actual value of the bit, 0 or 1." (Dkt. No. 140, at 7.) Plaintiff submits that the District of Delaware rejected Defendants' argument. (*Id.*)

At the June 1, 2022 hearing, Defendants argued that although the specification supports two interpretations of these disputed terms, and although both interpretations are reasonable, a person of ordinary skill in the art would be unable to determine which of these two different interpretations is correct. Defendants also argued that the construction by the District of

Delaware," construing "same bit value" to mean "value of the same bit," does not resolve this ambiguity. Plaintiff argued that Defendants are presenting a false dichotomy by attempting to distinguish between mapping a particular bit value (a "1" or a "0") and mapping a particular bit (which is at a particular position in a bit stream). Plaintiff argued that the claim language at issue simply recites that the value of a particular bit in the bit stream is modulated onto multiple carriers.

(b) Analysis

Claim 14 of the '008 Patent recites (emphasis added):

> 14. A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:
>
> associating each carrier signal with a value determined independently of any *bit value* of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;
>
> computing a phase shift for each carrier signal based on the value associated with that carrier signal; and
>
> combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the plurality of carrier signals, wherein *multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value*.

Defendants' expert opines that "same bit value" is unclear because it could refer to *either* the bit *position* or the *value* of the bit. (*See* Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl. at ¶¶ 75–82.)

Plaintiff cites the opinion of its expert that persons of skill in the art would have understood that the term "same bit value" refers to the "value of the same bit." (Dkt. No. 124, Ex. 11, Mar. 2022 Madisetti Decl. at ¶¶ 57–77.)

The construction of "same bit value" as meaning "value of the same bit" is consistent with disclosures in the specification regarding reducing PAR (peak-to-average power ratio) by

scrambling, thereby mitigating or avoiding clipping and excessive power consumption. *See id.* at ¶¶ 52–61. For example, the Background of the Invention section of the specification discloses:

> If the phase of the modulated carriers is not random, then the PAR can increase greatly. Examples of cases where the phases of the modulated carrier signals are not random are when bit scramblers are not used, multiple carrier signals are used to modulate the same input data bits, and the constellation maps, which are mappings of input data bits to the phase of a carrier signal, used for modulation are not random enough (i.e., a zero value for a data bit corresponds to a 90 degree phase characteristic of the DMT carrier signal and a one value for a data bit corresponds to a –90 degree phase characteristic of the DMT carrier signal). An increased PAR can result in a system with high power consumption and/or with high probability of clipping the transmission signal. Thus, there remains a need for a system and method that can effectively scramble the phase of the modulated carrier signals in order to provide a low PAR for the transmission signal.

’008 Patent at 2:15–30. The specification discloses using a phase scrambler to shift the phases of the carriers for particular bit values to reduce the PAR of the signal. *See id.* at 3:31–5:14; *see also* Dkt. No. 124, Ex. 11, Mar. 2022 Madisetti Decl. at ¶¶ 62–70.

Plaintiff also notes disclosure regarding scrambling by using phase shifts that are independent of the values of the input bits, such as that “[a] phase shift is computed for each carrier signal based on [a] value associated with that carrier signal” and “[t]he value is determined independently of any input bit value carried by that carrier signal.” ’008 Patent at 2:37–40 & 2:55–56; *see id*. at 4:48–63 (“The phase scrambler 66 determines each value for a carrier signal independently of the QAM symbols 58, and, therefore, independently of the bit value(s) modulated onto the carrier signal.”); *see also id*. at 5:2–3 (“When the equation is independent of the bit values of the input serial bit stream 54, the computed phase shifts are also independent of such bit values.”); Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl. at ¶ 78 (“In these passages, a person of ordinary skill would understand that the specification is referring to the value (0 or 1) of any given bit, rather than the specific position of the bit in the bit stream.”).

The District of Delaware rejected an indefiniteness argument as to related patents, namely United States Patents No. 8,073,041, 8,218,610, and 8,355,427:

> I am not persuaded by Defendants' argument that this term is indefinite because the patent is ambiguous as to the meaning of "same [input] bit value." (*Id.* at 67 (citing *Interval Licensing LLC v. AOL, Inc.*, 766 F.3d 1364, 1371 (Fed. Cir. 2014))). In my opinion, a person of ordinary skill in the art would read the term "same [input] bit value" as "value of the same bit." As I understand it, once the phase characteristics of the carrier signals have been adjusted by the phase scrambler in the transmitting transceiver, they are then demodulated by the phase descrambler in the receiving transceiver. (*See, e.g.*, '041 patent, 4:42–46; *see also* D.I. 365 at A327–28 ¶ 63). Thus, the transmitting transceiver and the receiving transceiver are complementary. The bit values that are demodulated on the receiving side mirror the bit values that are modulated on the transmitting side. It makes sense, therefore, that the term "same [input] bit value" refers to "value of the same bit."

Delaware Family 4 CC Opinion at 10. This analysis by the District of Delaware pertained to claims that involved demodulation, and the disputed term there at issue referred to "demodulat[ing] a same [input] bit value." Defendants argued at the June 1, 2022 hearing that the claim at issue in the present case is more confusing than the claims addressed by the District of Delaware because those claims referred specifically to "the received bit stream." *Nautilus*, however, requires "reasonable certainty," not "absolute precision." 134 S. Ct. at 2129. In the present case, the claim at issue recites "a first transceiver that uses a plurality of carrier signals for modulating a bit stream," and the claim uses the term "same bit value" in relation to the recital of "bit value[s] of the bit stream" that are modulated. The term "same bit value," and the construction of that term by the District of Delaware to mean "value of the same bit," are reasonably clear in the context of the recited bit stream, such that the value of a particular bit in the bit stream is modulated onto multiple carriers. The claim scope is thus reasonably clear. The opinions of Plaintiff's expert are further persuasive in this regard. (Dkt. No. 124, Ex. 11, Mar. 2022 Madisetti Decl. at ¶ 74.)

The provisional patent application cited by Defendants does not warrant finding otherwise. (*See* Dkt. No. 135, at 17; *see also id.*, Ex. 26, United States Provisional Patent Application No. 60/164,134, at 2 (discussing that "several modulated carriers may have the same phase" if, for example: "The same data bits are used to modulate multiple carriers. This would occur in cases where it was desired (or required) to send the same data bits on different carriers and then combine the results at the receiver in order to receive the bits at a lower Bit Error Rate (this is a well-known method for using frequency diversity to decrease the BER)."). The cited portions of the provisional patent application do not refer to bit "values" and therefore do not give rise to any ambiguity regarding the meaning of the term "same bit value."

In light of all of the foregoing, the indefiniteness opinions of Defendants' expert are unpersuasive. (Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl. at ¶¶ 75–82.) Defendants do not meet their burden to show any lack of reasonable certainty as to the scope of these terms. *See Nautilus*, 572 U.S. at 910; *see also Sonix*, 844 F.3d at 1377. Defendants also submit that "in the Delaware litigation, *TQ Delta itself* interpreted 'same bit value' according to the first understanding described above, *i.e.*, 'same bit position,'" arguing that the "second understanding" (same value) is "unreasonably broad and would render the entire term superfluous." (Dkt. No. 135, at 18–19 (quoting *id.*, Ex. 27, Joint Claim Construction Brief, at 64).) Defendants' argument that Plaintiff's interpretation of these terms is too broad is unpersuasive in light of the above-cited analysis by the District of Delaware as well as by this Court's analysis above. Also, as a more general matter, "breadth is not indefiniteness." *BASF Corp. v. Johnson Matthey Inc.*, 875 F.3d 1360, 1367 (Fed. Cir. 2017) (quoting *SmithKline Beecham Corp. v. Apotex Corp.*, 403 F.3d 1331, 1341 (Fed. Cir. 2005)).

Finally, because the parties have presented arguments only as to the construction of "same bit value" and not the remainder of the larger term "multiple carrier signals corresponding to the scrambled carrier signals are used by the first multicarrier transceiver to modulate the same bit value," no construction of that larger term is necessary (apart from the Court's construction of "same bit value").

The Court therefore hereby construes these disputed terms as set forth in the following chart:

Term	Construction
"same bit value"	**"value of the same bit"**
"multiple carrier signals corresponding to the scrambled carrier signals are used by the first multicarrier transceiver to modulate the same bit value"	**Plain meaning (apart from the Court's construction of "same bit value," above)**

16. "computing a phase shift for each carrier signal"

"computing a phase shift for each carrier signal" '008 Patent, Claim 14	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	"computing the amount by which a phase is adjusted for each carrier signal"

(Dkt. No. 107, Ex. A, at 82; *id.*, Ex. B, at 11–12; Dkt. No. 146, App'x A, at 8; Dkt. No. 149, App'x A, at 57.)

(a) The Parties' Positions

Plaintiff argues that "while the Delaware Court arrived at the construction Defendants propose, the Court addressed different issues . . . ." (Dkt. No. 124, at 19.) Plaintiff argues that

"[d]efining a 'shift' as 'the amount by which a phase is adjusted' does not help a jury beyond what the claims already recite," "[a]nd it appears that Defendants' construction calls for computing a specific 'amount' by which a phase is adjusted, while the plain language can encompass simply computing the fact that a phase shift exists." (*Id.*)

Defendants respond that determining the *existence* of a phase shift is not "computing" a phase shift. (Dkt. No. 135, at 19.)

Plaintiff replies that "[t]he claim omits the limitation 'computing the amount,' even though the specification uses the word 'amount of the phase shift' (in a different context, as described below), indicating that had the patentee intended to limit the claims to computing an amount, he could have done so." (Dkt. No. 140, at 8.)

(b) Analysis

Claim 14 of the '008 Patent recites (emphasis added):

> 14. A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:
>
> associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;
>
> *computing a phase shift for each carrier signal* based on the value associated with that carrier signal; and
>
> combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

In this context, interpreting "computing a phase shift for each carrier signal" as referring to the mere existence of a phase shift would be a far less natural reading than interpreting this term as referring to an amount by which a phase is adjusted. In particular, the limitation at issue refers to "computing a phase shift for each carrier signal *based on the value* associated with that

carrier signal," and Plaintiff does *not* persuasive show how "computing" a phase shift "based on" a "value" could encompass determining merely whether a phase shift exists or not.

This is also consistent with disclosure in the specification:

> The DMT transmitter 22 then *computes* (step 115) the phase shift that is used to adjust the phase characteristic of each carrier signal. The *amount* of the phase shift combined with the phase characteristic of each QAM-modulated carrier signal depends upon the equation used and the one or more values associated with that carrier signal.

'008 Patent at 6:41–46 (emphasis added). Plaintiff argues that this disclosure of an "amount" does not warrant interpreting "computing" to *require* determining an amount, Plaintiff arguing that "[t]his indicates that the amount of the phase shift depends on the equation used, not that the system must compute the amount." (Dkt. No. 140, at 8.) A fair reading of this disclosure, however, is that "computes" in the first sentence gives rise to the "amount" in the second sentence. *See* '008 Patent at 6:41–46; *see also id.* at 4:64–5:4 ("The phase scrambler 66 then solves a predetermined equation to compute a phase shift for the carrier signal . . . .") & 9:16–28 ("Because the generation of phase shifts in this embodiment is based on values that vary over time, the phase shifts computed for the subsequent DMT symbol 70' are different than those that were previously computed for the DMT symbol 70 with the clipped time domain sample.").

This interpretation of the claim language is also consistent with the construction reached by the District of Delaware for the same term in the same claim, wherein the court rejected Plaintiff's proposal of a plain and ordinary meaning construction and instead construed "computing a phase shift for each carrier signal" to mean "computing the amount by which a phase is adjusted for each carrier signal," which is the construction that Defendants propose in the present case. *Delaware Family 4 CC Opinion* at 17–18. The District of Delaware construed

the constituent term "phase shift" to mean "the amount by which a phase is adjusted," Plaintiff there having proposed "the amount by which a phase is (or will be) shifted." *Id.* at 12–14.

Plaintiff argues that the District of Delaware "addressed different issues (whether a phase shift was the '*angle* by which the phase . . . is *rotated'* and whether it was necessary to expressly include in the construction retrospective, contemporaneous, and prospective phase shifts)." (Dkt. No. 124, at 19–20.) In light of the foregoing, Plaintiff does not persuasively justify departing from the construction reached by the District of Delaware, particularly as to Plaintiff's suggestion that this term could encompass determining the mere existence of a phase shift.

The Court therefore hereby construes **"computing a phase shift for each carrier signal"** to mean **"computing the amount by which a phase is adjusted for each carrier signal."**

17. "combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal"

"combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal" '008 Patent, Claim 14	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	"adjusting the phase of each carrier signal by an amount computed for that carrier signal"

(Dkt. No. 107, Ex. A, at 83; Dkt. No. 146, App'x A, at 8; Dkt. No. 149, App'x A, at 58.)

<u>(a) The Parties' Positions</u>

Plaintiff argues that while "[i]t is true that the Delaware Court entered the Defendants' proposed construction (which was agreed to)," "Defendants' proposed construction largely

copies over its 'phase shift' proposal and may be read to overly limit this term for the same reasons." (Dkt. No. 124, at 20 (citation omitted).)

Defendants respond by incorporating their arguments as to the term "computing a phase shift for each carrier signal," which is discussed above. (Dkt. No. 135, at 19–20.) Plaintiff replies likewise. (*See* Dkt. No. 140, at 7–8.)

(b) Analysis

Claim 14 of the '008 Patent recites (emphasis added):

> 14. A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:
>
> associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;
>
> computing a phase shift for each carrier signal based on the value associated with that carrier signal; and
>
> *combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal* to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

This term presents substantially the same dispute as the term "computing a phase shift for each carrier signal," which is discussed above, and for essentially the same reasons the Court expressly rejects Plaintiff's argument that "the phase shift computed for each respective carrier signal" could refer to merely the existence of a phase shift.

Defendants' proposal, however, would tend to confuse rather than clarify the scope of the disputed term. Instead, this dispute is already adequately addressed by the Court's construction of "computing a phase shift for each carrier signal," above. No further construction is necessary. *See U.S. Surgical*, 103 F.3d at 1568; *see also O2 Micro*, 521 F.3d at 1362; *Finjan*, 626 F.3d at 1207; *ActiveVideo*, 694 F.3d at 1326; *Summit 6*, 802 F.3d at 1291; *Bayer*, 989 F.3d at 977–79.

The Court therefore hereby construes **"combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal"** to have its **plain meaning.**

IX. DISPUTED TERMS IN THE "FAMILY 6" PATENTS

Plaintiff submits that "[t]he Family 6 Patents generally relate to techniques to adapt noise protection to changing conditions while continuing to communicate data." (Dkt. No. 124, at 1 (citation omitted).)

The '835 Patent, for example, titled "Impulse Noise Management," issued on June 11, 2013, and bears an earliest priority date of March 3, 2004. The Abstract of the '835 Patent states:

> Evaluation of the impact of impulse noise on a communication system can be utilized to determine how the system should be configured to adapt to impulse noise events. Moreover, the system allows for information regarding impulse noise events, such as length of the event, repetition period of the event and timing of the event, to be collected and forwarded to a destination. The adaptation can be performed during one or more of Showtime and initialization, and can be initiated and determined at either one or more of a transmitter and a receiver.

18. "steady-state communication"

"steady-state communication" '835 Patent, Claim 8 '112 Patent, Claim 8	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"Showtime"	"the state of the transceiver reached after all initialization and training is completed in which user data is transmitted or received"

(Dkt. No. 107, Ex. A, at 85; *id.*, Ex. B, at 14–15; Dkt. No. 146, App'x A, at 8; Dkt. No. 149, App'x A, at 59.)

(a) The Parties' Positions

Plaintiff argues that whereas "Defendants' proposal is what the parties agreed to in Delaware," Plaintiff's proposal "matches the specification's definition." (Dkt. No. 124, at 20–21 (citation omitted).)

Defendants respond that "Defendants' proposed construction is consistent with the plain and ordinary meaning of the term 'steady-state communication,' while TQ Delta's construction limits the term to an example embodiment in the specification." (Dkt. No. 135, at 20 (citations omitted).) Defendants argue that "the specification explains that 'steady-state communication' may be consistent with 'Showtime' *for DSL technologies*, but the claims are not limited to DSL technologies." (*Id.*)

Plaintiff replies that "[i]n five places, the Patents define a steady-state communication as "Showtime," and "[t]he term 'Showtime' appears over 50 times, reinforcing that the Family 6 Patents are about xDSL systems." (Dkt. No. 140, at 8 (citing '348 Patent at 2:43–49, 4:3–7, 4:25–31, 8:25–27 & 9:40–43).)

(b) Analysis

Claim 8 of the '835 Patent, for example, recites (emphasis added):

> 8. An apparatus configurable to adapt forward error correction and interleaver parameter (FIP) settings during *steady-state communication* or initialization comprising:
> a transceiver, including a processor, configurable to:
> transmit a signal using a first FIP setting,
> transmit a flag signal, and
> switch to using for transmission, a second FIP setting following transmission of the flag signal,
> wherein:
> the first FIP setting comprises at least one first FIP value,
> the second FIP setting comprises at least one second FIP value, different than the first FIP value, and

> the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

The specification discloses:

> The current technique includes the steps of an operator, or service provider, configuring the ADSL connection with a specific noise protection value, the ADSL connection is initialized and the transceivers enter into steady state data transmission (i.e., Showtime), and if the connection is stable, i.e., error-free, then the service is acceptable and the process ends.
>
> * * *
>
> The process of determining the impact of impulse noise by transmitting and receiving using a plurality of FIP settings can be done while in steady-state transmission, i.e., Showtime for DSL systems, when user information bits are being transmitted.

'835 Patent at 2:42–49 & 4:3–7; *see id.* at 4:25–31 ("steady-state transmission during which user information is transmitted is known as 'Showtime' in XDSL systems"), 8:25–27 ("regular, i.e., Showtime, operation") & 9:40–43 ("regular steady-state transmission, i.e., Showtime in ADSL").

In general, "the usage 'i.e.' ('id est' or 'that is'), 'signals an intent to define the word to which it refers.'" *TF3 Ltd. v. Tre Milano, LLC*, 894 F.3d 1366, 1372 (Fed. Cir. 2018) (quoting *Edwards Lifesciences LLC v. Cook Inc.*, 582 F.3d 1322, 1334 (Fed. Cir. 2009)); *see TF3*, 894 F.3d at 1372 ("'i.e.' is definitional when it 'comports with the inventors' other uses . . . in the specification and with each and every other reference") (quoting *SkinMedica, Inc. v. Histogen Inc.*, 727 F.3d 1187, 1202 (Fed. Cir. 2013)).

Here, however, several of the above-cited disclosures imply that "DSL systems" are an example rather than a necessary limitation. *See* '835 Patent at 4:3–7 ("i.e., Showtime *for DSL systems*"); *see also id.* at 4:25–31 & 9:40–43 (quoted above). Thus, despite the patentee's use of "i.e.," the patentee did not clearly define the disputed claim term as meaning "Showtime." *See CCS Fitness, Inc. v. Brunswick Corp.*, 288 F.3d 1359, 1366 (Fed. Cir. 2002) ("[T]he claim term

will not receive its ordinary meaning if the patentee acted as his own lexicographer and *clearly* set forth a definition of the disputed claim term in either the specification or prosecution history.") (citation omitted; emphasis added). Plaintiff does not otherwise persuasively show that the claims here at issue are limited to DSL.

Also of note, the construction proposed by Defendants is a construction that Plaintiff agreed to in the District of Delaware. *See TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA (D. Del.), Dkt. No. 183, Aug. 23, 2017 Joint Claim Construction Chart, at 6. The construction agreed upon in that case is also consistent with disclosure in the specification, such as that "*steady-state transmission during which user information is transmitted* is known as 'Showtime' in XDSL systems" and "standard ITU G.992.3 ADSL systems and ITU VDSL G.993.3 systems include an exchange phase in initialization during which the Showtime parameters are exchanged." '835 Patent at 4:19–31 (emphasis added).

The Court therefore hereby construes **"steady-state communication"** to mean **"the state of the transceiver reached after all initialization and training is completed in which user data is transmitted or received."**

19. "FIP setting"

20. "FIP value"

"FIP setting" '835 Patent, Claims 8, 10, 26; '112 Patent, Claim 8	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	"forward error correction and interleaver parameters characterized by the set of parameters for codeword size in bytes, number of information bytes in a codeword, number of parity or redundancy bytes in a codeword, and interleaver depth in number of codewords"
"FIP value" '835 Patent, Claim 8	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	"numerical value of codeword size in bytes, number of information bytes in a codeword, number of parity or redundancy bytes in a codeword, or interleaver depth in number of codewords"

(Dkt. No. 107, Ex. A, at 87 & 89; *id.*, Ex. B, at 13; Dkt. No. 146, App'x A, at 8–9; Dkt. No. 149, App'x A, at 61 & 63.)

(a) The Parties' Positions

Plaintiff argues that "Defendants propose a construction for these terms that the Delaware Court correctly rejected." (Dkt. No. 124, at 23.) Plaintiff submits that "'FIP' is an acronym for 'Forward Error Correction and Interleaving,'" and "[a] FIP setting (or value) simply refers to forward error correction and interleaver parameters (or values)." (*Id.*)

Defendants respond that "[b]ecause the Family 6 Patents define 'FIP Settings' as the N, K, R, and D parameters with particular definitions in the specification, the Court should construe the term consistent with Defendants' proposed construction." (Dkt. No. 135, at 22.) Defendants also argue: "TQ Delta provides no justification for its plain-and-ordinary-meaning construction beyond citing the Delaware court's opinion on this term. That court incorrectly held that an extrinsic standard referenced in the Family 6 Patents shows that the FIP Settings may comprise additional parameters other than the N, K, R, and D parameters." (*Id.*, at 23 (citation omitted).)

Plaintiff replies: "Defendants ignore the provisional application's disclosure of 'FIP settings' and 'FIP values'—which includes parameters besides the four that Defendants limit this term to. Opening Br. at 22–24. That disclosure shows that Defendants' construction is wrong. The remainder of Defendants' arguments were rejected by the Delaware Court (*e.g.*, that measuring interleaver depth is not limited to 'codeword size'), holdings that Defendants do not substantively address." (Dkt. No. 140, at 9.)

<u>(b) Analysis</u>

Claim 8 of the '835 Patent, for example, recites (emphasis added):

> 8. An apparatus configurable to adapt *forward error correction and interleaver parameter (FIP) settings* during steady-state communication or initialization comprising:
>
> a transceiver, including a processor, configurable to:
>
> transmit a signal using a first *FIP setting*,
>
> transmit a flag signal, and
>
> switch to using for transmission, a second *FIP setting* following transmission of the flag signal,
>
> wherein:
>
> the first *FIP setting* comprises at least one first *FIP value*,
>
> the second *FIP setting* comprises at least one second *FIP value*, different than the first *FIP value*, and
>
> the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

The parties agree that "FIP" is an acronym for "forward error correction and interleaver parameter," which is apparent on the face of above-reproduced Claim 8. *See also* '835 Patent at 3:31–34 ("FEC and Interleaving Parameter (FIP) setting").

Defendants propose a construction for "FIP setting" that the District of Delaware rejected, finding that whereas "Defendants improperly limit 'FIP setting' to exactly four parameters, and only those parameters," "[a] 'FIP setting' may include other parameters." *Delaware Family 6 CC Opinion* at 12. The Delaware court adopted the construction proposed by Plaintiff in that case, namely "set including at least one forward error correction parameter value and at least one interleaver parameter value." *Id.* at 11–12. The Delaware court similarly adopted Plaintiff's proposal to construe "FIP value" to mean "numerical value of a forward error correction parameter or numerical value of an interleaver parameter." *Id.* at 12–13.

Defendants argue that the terms "FIP setting" and "FIP value" have *not* been known terms of art outside of the Family 6 Patents. For example, Defendants' expert opines: "While a person of ordinary skill in the art would have generally understood that the processes of forward error correction encoding and interleaving are usually governed by certain parameters, a person of ordinary skill in the art would have been unfamiliar with the particular initialism 'FIP' as used in the Family 6 Patents." (*See* Dkt. No. 135, Ex. 23, Mar. 14, 2022 McNair Decl., at ¶ 58.) Defendants argue that the meanings of these terms should be limited to the parameters disclosed for these terms in the specification. (*See id.* at ¶ 59; *see also* '835 Patent at 1:65–2:20.)

As a general matter, in some cases, a term that has no well-established meaning "cannot be construed broader than the disclosure in the specification." *Indacon, Inc. v. Facebook, Inc.*, 824 F.3d 1352, 1357 (Fed. Cir. 2016); *see Intervet, Inc. v. Merial Ltd.*, 617 F.3d 1282, 1287 (Fed. Cir. 2010) ("Idiosyncratic language, highly technical terms, or terms coined by the inventor

are best understood by reference to the specification.") (citing *Phillips*, 415 F.3d at 1315); *see also Irdeto Access, Inc. v. EchoStar Satellite Corp.*, 383 F.3d 1295, 1300 (Fed. Cir. 2004) ("absent . . . an accepted meaning [in the art], we construe a claim term only as broadly as provided for by the patent itself").

Here, however, Defendants acknowledge that forward error correction and interleaving were known concepts at the time of the claimed inventions. (*See* Dkt. No. 135, Ex. 23, Mar. 14, 2022 McNair Decl., at ¶ 58.) The patentee's use of the acronym "FIP" did not erase what a person of ordinary skill in the art at the relevant time would have known about parameters for forward error correction and interleaving.

The Court therefore reaches the same conclusions and constructions as the District of Delaware for these terms, and the Court accordingly hereby construes these disputed terms as set forth in the following chart:

Term	Construction
"FIP setting"	**"set including at least one forward error correction parameter value and at least one interleaver parameter value"**
"FIP value"	**"numerical value of a forward error correction parameter or numerical value of an interleaver parameter"**

21. "flag signal"

"flag signal" '835 Patent, Claim 8 '162 Patent, Claims 8, 9	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"signal used to indicate when an updated FIP setting / interleaver parameter value is to be used (the signal does not contain message data indicating when the updated FIP setting / interleaver parameter value is to be used)"	"signal used to indicate when updated FIP settings / interleaver parameter values are to be used"

(Dkt. No. 107, Ex. A, at 90–91; *id.*, Ex. B, at 14; Dkt. No. 146, App'x A, at 9; Dkt. No. 149, App'x A, at 64.)

(a) The Parties' Positions

Plaintiff submits that "[b]oth parties propose the same affirmative construction," and "TQ Delta does not believe there is a claim-scope dispute between the parties on this term." (Dkt. No. 124, at 21.) Plaintiff also submits that "[t]he parenthetical that TQ Delta proposes was agreed-to in the Delaware case" and "clarifies what the affirmative construction already states—that a flag signal is different than message data, a distinction reflected in the intrinsic record." (*Id.* (citations omitted).)

Defendants respond that "TQ Delta's construction adds a negative limitation that finds no support in the specification." (Dkt. No. 135, at 21.)

Plaintiff responds: "Defendants do not identify a claim-scope dispute with TQ Delta's proposed construction, which was agreed-to in Delaware. A flag signal, as the Patents teach (Opening Br. at 21), is different than message data, which Defendants do not meaningfully contest." (*Id.*, at 8–9.)

In a supplemental brief permitted by leave of Court (*see* Dkt. Nos. 159), Defendants submit Preliminary Responses filed by Plaintiff on May 25, 2022, in *Inter Partes* Review ("IPR") proceedings being conducted by the Patent Trial and Appeal Board ("PTAB") regarding the '835 Patent. (*See* Dkt. No. 157.) Defendants argue that Plaintiff, in these Preliminary Responses, argues that the construction by the District of Delaware was wrong and also proposes a parenthetical that is different than what Plaintiff proposes for the construction in the present case. (*See id.*, at 1.) Defendants argue that "TQ Delta appears to be strategically taking different positions in district court and before the PTAB to try to preserve the validity of the '835 patent over the prior art." (*Id.*, at 2.)

(b) Analysis

Claim 8 of the '835 Patent, for example, recites (emphasis added):

> 8. An apparatus configurable to adapt forward error correction and interleaver parameter (FIP) settings during steady-state communication or initialization comprising:
> a transceiver, including a processor, configurable to:
> transmit a signal using a first FIP setting,
> transmit a *flag signal*, and
> switch to using for transmission, a second FIP setting following transmission of the *flag signal*,
> wherein:
> the first FIP setting comprises at least one first FIP value,
> the second FIP setting comprises at least one second FIP value, different than the first FIP value, and
> the switching occurs on a pre-defined forward error correction codeword boundary following the *flag signal*.

The District of Delaware adopted a parenthetical that appeared in "compromise constructions" submitted by each side in that case. *See Delaware Family 6 CC Opinion* at 4. That is, each side proposed a main construction and a compromise construction, and although the compromise constructions differed from one another, both compromise constructions included

nearly the same parenthetical (defendant's proposed parenthetical referred to a "FEC codeword counter value" and Plaintiff's proposed parenthetical referred to a "FEC codeword counter," without the word "value"). *Id.*

The District of Delaware adopted the proposal by the defendants in that case, such that the District of Delaware construed "flag signal" to mean "signal used to indicate when an updated FIP setting is to be used (the signal does not include the FEC codeword counter value upon which the updated FIP setting is to be used)." *Id.* at 5; *see id.* at 4–6.

Plaintiff proposes a parenthetical different from the one adopted by the District of Delaware, and Plaintiff cites disclosure in the specification:

> FIG. 6 illustrates an exemplary method of synchronization using a flag signal according to this invention. In particular, control begins in step S600 and continues to step S610. In step S610, the modems enter Showtime using the first FIP parameters. Next, in step S620, a message is exchanged indicating the new FIP settings. Then, in step S630, the transmitter forwards to the receiver a *flag signal* indicating when the new FIP settings are to be used.
>
> At step S640, and *at a predefined change time following the transmission of the flag signal*, the transmitter begins transmission using the new FIP parameters. Next, at step S650, at the *predefined change time following the reception of the flag signal*, the receiver commences reception utilizing the new FIP parameters. Control then continues to step S660 where Showtime communication continues with the control sequence ending at step S670.

'835 Patent at 19:14–30.

The disclosure thus explains that, in this embodiment, the "flag signal" does not itself specify a time but rather there is a "predefined change time following the transmission of the flag signal." *Id.* In other words, a "flag signal" is a signal *to* change, not a signal of *when* to change. Other disclosure in the specification is similar in this regard. *See id.* at 11:66–12:24 ("For synchronization using a flag signal, the receiver and transmitter would start using updated FEC and interleaving parameters on a pre-defined FEC codeword boundary following the sync flag.").

Construing the term "flag signal" in light of this disclosure in the specification does not improperly limit the term to a particular embodiment because the surrounding claim language, such as in above-reproduced Claim 8 of the '835 Patent, recites that "the switching occurs on a *pre-defined* forward error correction codeword boundary *following the flag signal*." This usage of "pre-defined" and "following" demonstrates that a "flag signal" does not itself set forth a change time but rather is merely an indication that the updated FIP setting / interleaver parameter value should be used at some juncture that is pre-defined in relation to when the flag signal is received. The specification contrasts this with other synchronization methods, such as using codeword counters. *See id.* at 8:67–9:2 (. . . at a synchronized point in time"), 9:23–27 ("this transition can be synchronized using a number of different exemplary methods"), 11:10–65 ("counting the FEC codewords from the beginning of Showtime and the transition would occur when a specific FEC codeword counter value that is known by both the transmitter 300 and the receiver 200 is reached") & 18:61–19:10 ("a message with the FEC codeword counter value on which the new FIP values are to be used is exchanged" and "a determination is made whether the counter value has been reached").

Finally, as to Defendants' supplemental submission of IPR Preliminary Responses that Plaintiff filed with the PTAB, those Preliminary Responses set forth a proposal by Plaintiff to construe "flag signal" to mean "signal used to indicate when an updated FIP setting is to be used, where the signal does not include information (*e.g.*, a FEC codeword counter value) specifying when the updated FIP setting is to be used." (Dkt. No. 157, Ex. 37, May 25, 2022 Patent Owner's Preliminary Response, at 9; *see id.* at 5–9; *see also id.*, Ex. 38, May 25, 2022 Patent Owner's Preliminary Response, at 6–9.) These Preliminary Responses do not affect the Court's analysis, particularly given that Plaintiff states in these Preliminary Responses that the

parenthetical set forth by the District of Delaware in its claim construction is "accurate" (albeit, Plaintiff argues, "incomplete"). For the reasons set forth above, the Court adopts the District of Delaware construction rather than the construction proposed by Plaintiff in the present case, so Defendants' reliance on the Preliminary Responses to undermine Plaintiff's proposal, even if found persuasive, would be of no significant effect. Plaintiff's arguments in the Preliminary Responses also present nothing that would warrant abandoning the parenthetical adopted by the District of Delaware that the Court here, too, finds appropriate to make clear that a "flag signal" does not include a counter value upon which an updated FIP setting will be used, as discussed above.

The Court therefore hereby construes **"flag signal"** to mean **"signal used to indicate when an updated FIP setting is to be used (the signal does not include the FEC codeword counter value upon which the updated FIP setting is to be used)."**

22. "interleaver parameter value"

"interleaver parameter value" '835 Patent, Claims 10, 26; '162 Patent, Claim 8	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	"the numerical value of the interleaver depth in number of codewords"

(Dkt. No. 107, Ex. A, at 93; *id.*, Ex. B, at 14; Dkt. No. 146, App'x A, at 9; Dkt. No. 149, App'x A, at 65.)

<u>(a) The Parties' Positions</u>

Plaintiff argues:

> The plain-and-ordinary meaning of this term references the interleaver depth, which is a value that can be expressed in multiple ways, such as bits, bytes, or codewords (just like distance can be expressed in inches, feet, and yards). Defendants' proposal improperly limits the term to *one* way to express that depth: "in number of codewords." This improperly limits the claims to one disclosed example. And the Delaware Court rejected the same attempt to improperly limit the claims.

(Dkt. No. 124, at 22 (citation omitted).)

Defendants respond that "similar to 'FIP Setting,' 'interleaver parameter value' was not a term of art at the time of the alleged invention and did not have a generally understood meaning," so "a POSITA [(person of ordinary skill in the art)] would have looked to the specification of the Family 6 Patents to understand the term 'interleaver parameter value,' which defines the term as 'interleaver depth in number of codewords.'" (Dkt. No. 135, at 23 (citations omitted).)

Plaintiff replies as to this term together with its reply as to "FIP setting" and "FIP value," which are addressed above. (Dkt. No. 140, at 9.)

<u>(b) Analysis</u>

Claim 10 of the '835 Patent, for example, recites (emphasis added):

> 10. The apparatus of claim 8, wherein a first *interleaver parameter value* of the first FIP setting is different than a second *interleaver parameter value* of the second FIP setting.

The District of Delaware rejected a proposal by the defendants in that case to construe this disputed term to mean "the numerical value of the interleaver depth in number of codewords." *Delaware Family 6 CC Opinion* at 7. The District of Delaware found that "[b]ecause 'interleaver depth' can be measured using a unit other than 'number of codewords,' the specification's reference to measuring 'interleaver depth' 'in number of codewords' must be a mere embodiment." *Id.* at 8; *see id.* at 8–9.

The District of Delaware construed "interleaver parameter value" to mean "numerical value of the interleaver depth." *Id.* at 7; *see id.* at 7–11.

Defendants argue that their proposal of "number of codewords" is based on a definition of the term "interleaver parameter value" in the specification, but a lexicography must be clear, and the disclosures cited by Defendants relate to specific embodiments and do not purport to define the term "interleaver parameter value" in general. *See* '162 Patent at 2:10–22, 3:33–49 & 13:43–47; *see also CCS Fitness*, 288 F.3d at 1366 ("[T]he claim term will not receive its ordinary meaning if the patentee acted as his own lexicographer and *clearly* set forth a definition of the disputed claim term in either the specification or prosecution history.") (citation omitted; emphasis added).

The opinions of Defendants' expert do not compel otherwise. (*See* Dkt. No. 135, Ex. 23, Mar. 14, 2022 McNair Decl., at ¶¶ 58–61.) In particular, Defendants' expert opines that "[w]hile a person of ordinary skill in the art would have generally understood that the processes of forward error correction encoding and interleaving are usually governed by certain parameters, a person of ordinary skill in the art would have been unfamiliar with the particular initialism 'FIP' as used in the Family 6 Patents," and "[b]ecause the Family 6 Patents specially define the term 'FIP,' a person of ordinary skill in the art would have understood the Family 6 Patents to be referring to particular FEC and interleaving parameters as explained in the Family 6 Patents." (*Id.*, at ¶ 58.) The patentee's use of the acronym "FIP" did not erase what a person of ordinary skill in the art at the relevant time would have known about parameters for interleaving and, as noted above, the patentee did not set forth any clear lexicography.

Thus, Defendants do not persuasively justify limiting the construction to "number of codewords" or otherwise departing from the Delaware construction.

The Court therefore hereby construes **"interleaver parameter value"** to mean **"numerical value of the interleaver depth."**

X. DISPUTED TERMS IN THE "FAMILY 9" PATENTS

Plaintiff submits that "[t]he Family 3 and 9 Patents generally relate to sharing resources, such as sharing memory between an interleaver and deinterleaver or a transmission function and a retransmission function." (Dkt. No. 124, at 1 (citation omitted).)

The '348 Patent, for example, titled "Packet Retransmission," issued on July 28, 2015, and bears an earliest priority date of April 12, 2006. The Abstract of the '348 Patent states:

> Through the identification of different packet-types, packets can be handled based on an assigned packet handling identifier. This identifier can, for example, enable forwarding of latency-sensitive packets without delay and allow error-sensitive packets to be stored for possible retransmission. In another embodiment, and optionally in conjunction with retransmission protocols including a packet handling identifier, a memory used for retransmission of packets can be shared with other transceiver functionality such as, coding, decoding, interleaving, deinterleaving, error correction, and the like.

As to the term "receive at least one message without using interleaving" in Claims 37 and 53 of the '577 Patent, Plaintiff states in its Reply Claim Construction Brief that "TQ Delta omitted the claims in which this term appears from its Preliminary Election of Asserted Claims. TQ Delta thus submits that the Court need not address this term." (Dkt. No. 140, at 9.) Because Plaintiff no longer asserts the claims in which this term appears, the Court does not further address this term.

Also, the term "memory has been allocated" ('411 Patent, Claim 10) appears in Defendant's portion of the Joint Claim Construction and Prehearing Statement, but this term is not addressed in the parties' briefing. The Court therefore does not further address this term.

23. "higher immunity to noise"

"higher immunity to noise" '348 Patent, Claim 2	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
"higher SNR margin"	Plain and ordinary meaning

(Dkt. No. 107, Ex. A, at 95; *id.*, Ex. B, at 16; Dkt. No. 146, App'x A, at 9; Dkt. No. 149, App'x A, at 66.)

(a) The Parties' Positions

Plaintiff argues that "[t]he Court should construe this term to help the jury understand the claims," and "[t]he Patents explain that messages have 'higher immunity to noise' than a packet because they have a higher signal-to-noise (known as 'SNR') margin (which reflects the margin between the strength of the signal and the noise, typically expressed in decibels (dB))." (Dkt. No. 124, at 24 (citing '348 Patent at 16:4–9).)

Defendants respond that "TQ Delta provides no reason why the term should be limited to just one example (among several) referenced in the specification." (Dkt. No. 135, at 25 (citation omitted).)

Plaintiff replies that "[t]he only part of the Patents that mention messages that have a higher immunity to noise ties it to a higher SNR margin." (Dkt. No. 140, at 9 (citing '348 Patent at 16:4–9).) Plaintiff argues that "[w]hile Defendants note that this disclosure is an 'alternative[]' ('or in addition') embodiment, the claims are dependent claims drawn to that embodiment," "[a]nd Defendants' cited portions do not refer to a message having a higher immunity to noise (they mention 'robustness,' including by sending the same message multiple times)." (*Id.*, at 9.)

(b) Analysis

Claims 1, 2, 9, and 10 of the ’348 Patent, for example, recite (emphasis added):

> 1. An apparatus comprising:
> a multicarrier transceiver including a processor and memory operable to:
> *transmit a packet* using a forward error correction encoder and an interleaver, wherein the packet comprises a header field and a plurality of PTM-TC codewords, a plurality of ATM cells or a plurality of Reed-Solomon codewords, and wherein the header field comprises a sequence identifier (SID); and
> *receive a plurality of messages* using a forward error correction decoder and without using a deinterleaver, wherein each message of the plurality of messages is received in a different DMT symbol and wherein at least one message of the plurality of messages includes an acknowledgement (ACK) or a negative acknowledgement (NACK) of the transmitted packet.
>
> 2. The apparatus of claim 1, wherein the received messages have a *higher immunity to noise* than the transmitted packet.
>
> * * *
>
> 9. An apparatus comprising:
> a multicarrier transceiver including a processor and memory operable to:
> *receive a packet* using a forward error correction decoder and a deinterleaver, wherein the packet comprises a header field and a plurality of PTM-TC codewords, a plurality of ATM cells or a plurality of Reed-Solomon codewords, and wherein the header field comprises a sequence identifier (SID); and
> *transmit a plurality of messages* using a forward error correction encoder and without using an interleaver, wherein each message of the plurality of messages is transmitted in a different DMT symbol and wherein at least one message of the plurality of messages includes an acknowledgement (ACK) or a negative acknowledgement (NACK) of the received packet.
>
> 10. The apparatus of claim 9, wherein the transmitted messages have a *higher immunity to noise* than the received packet.

The specification discloses:

> Alternatively, or in addition, the DMT sub-carriers that modulate these messages could operate with a much *higher SNR margin* e.g., 15 dB, as compared to the normal 6 dB margin of xDSL systems. This way, the messages would have a *higher immunity to channel noise*.

’348 Patent at 16:4–9 (emphasis added).

The specification thus discloses that having a "higher SNR margin" (which is the construction proposed by Plaintiff) is *a manner in which* "higher immunity to noise" can be achieved. This does not mean that having "higher immunity to noise" necessary involves a higher SNR margin. For example, the specification also discloses that "messages can be sent with increasing robustness by repeating transmission of each message a number of times." *Id.* at 15:33–35. Plaintiff's proposal would improperly limit the disputed term to a specific feature of a particular disclosed embodiment and should be rejected. *See Phillips*, 415 F.3d at 1323.

The Court therefore hereby expressly rejects Plaintiff's proposed construction, and no further construction is necessary. *See U.S. Surgical*, 103 F.3d at 1568; *see also O2 Micro*, 521 F.3d at 1362; *Finjan*, 626 F.3d at 1207; *ActiveVideo*, 694 F.3d at 1326; *Summit 6*, 802 F.3d at 1291; *Bayer*, 989 F.3d at 977–79.

The Court accordingly hereby construes **"higher immunity to noise"** to have its **plain meaning**.

24. "PTM-TC [(Packet Transfer Mode Transmission Convergence)] codewords"

"PTM-TC [(Packet Transfer Mode Transmission Convergence)] codewords" '577 Patent, Claims 17, 37 '348 Patent, Claims 1, 9 '055 Patent, Claim 17	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary	(None)

(Dkt. No. 107, Ex. A, at 96.)

Plaintiff submits: "TQ Delta also proposed '[p]lain and ordinary meaning. No construction necessary' for the term 'PTM-TC [(Packet Transfer Mode Transmission

Convergence)] codewords' found in claims 17 and 37 of the '577 Patent, claims 1 and 9 of the '348 Patent, and claim 17 of the '055 Patent. Dkt. 107-1, at 96. Defendants did not propose a construction for this term. *See generally* Dkt. 107-2." (Dkt. No. 124, at 2 n.1.)

Defendants have not proposed a construction for this term and have not addressed this term in their responsive claim construction brief. At the June 1, 2022 hearing, the parties confirmed that this term is no longer in dispute, and Defendants agreed that this term has its plain and ordinary meaning.

The Court therefore hereby construes **"PTM-TC [(Packet Transfer Mode Transmission Convergence)] codewords"** to have its **plain meaning**.

25. "receive at least one packet using deinterleaving"

26. "[transmit/retransmit] at least one packet using interleaving"

27. "[transmit/receive] a [packet/plurality of messages] using a forward error correction [encoder/decoder] and [without using] [an/a interleaver/deinterleaver]"

28. "transmitting, by the transceiver, a packet using a forward error correction encoder and an interleaver"

29. "receiving, by the transceiver, at least one message using a forward error correction decoder and without using a deinterleaver"

30. "[transmitting/transmit/receiving/receive] a [packet/message] using forward error correction [encoding/decoding] and [without using] [interleaving/deinterleaving]"

31. "[retransmit/retransmitting] the packet using [the] forward error correction [encoder/encoding] and [the interleaver/interleaving]"

32. "[receive/receiving] a retransmitted packet using [the] forward error correction [decoder/decoding] and [the deinterleaver/deinterleaving]"

"receive at least one packet using deinterleaving" '577 Patent, Claim 16 **"[transmit/retransmit] at least one packet using interleaving"** '577 Patent, Claims 37, 38, 53, 54

“[transmit/receive] a [packet/plurality of messages] using a forward error correction [encoder/decoder] and [without using] [an/a interleaver/deinterleaver]” ’348 Patent, Claims 1, 9 “transmitting, by the transceiver, a packet using a forward error correction encoder and an interleaver” ’4473 Patent, Claim 1 “receiving, by the transceiver, at least one message using a forward error correction decoder and without using a deinterleaver” ’4473 Patent, Claim 1 “[transmitting/transmit/receiving/receive] a [packet/message] using forward error correction [encoding/decoding] and [without using] [interleaving/deinterleaving]” ’809 Patent, Claim 8 “[retransmit/retransmitting] the packet using [the] forward error correction [encoder/encoding] and [the interleaver/interleaving]” ’348 Patent, Claim 3 ’4473 Patent, Claim 3 ’809 Patent, Claims 3, 17 “[receive/receiving] a retransmitted packet using [the] forward error correction [decoder/decoding] and [the deinterleaver/deinterleaving]” ’348 Patent, Claim 11 ’809 Patent, Claim 10	
Plaintiff’s Proposed Construction	**Defendants’ Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Indefinite

(Dkt. No. 107, Ex. A, at 98–107; *id.*, Ex. B, at 16; Dkt. No. 124, at 25 n.21; Dkt. No. 146, App’x A, at 10; Dkt. No. 149, App’x A, at 67; Dkt. No. 149, App’x A, at 67–69.)

The following terms do not appear in the parties’ P.R. 4-5(d) Joint Claim Construction Chart (*see* Dkt. No. 149, App’x A): “[transmit/retransmit] at least one packet using interleaving” (’577 Patent, Claims 37, 38, 53, 54); “transmitting, by the transceiver, a packet using a forward error correction encoder and an interleaver” (’4473 Patent, Claim 1); “receiving, by the transceiver, at least one message using a forward error correction decoder and without using a

deinterleaver" ('4473 Patent, Claim 1); "[retransmit/retransmitting] the packet using [the] forward error correction [encoder/encoding] and [the interleaver/interleaving]" ('348 Patent, Claim 3; '4473 Patent, Claim 3; '809 Patent, Claims 3, 17); and "[receive/receiving] a retransmitted packet using [the] forward error correction [decoder/decoding] and [the deinterleaver/deinterleaving]" ('348 Patent, Claim 11; '809 Patent, Claim 10). The analysis set forth herein therefore does not address these terms.

(a) The Parties' Positions

Plaintiff argues that "[t]he plain language of the claims shows that interleaving and encoding functionality is part of the transmitter portion and that deinterleaving and decoding functionality is part of the receiving portion," and "[t]he specification matches the claims." (Dkt. No. 124, at 26.)

Defendants respond that these terms are not reasonably clear "because interleaving and deinterleaving functionalities do not actually transmit or receive data; rather, the transmitter transmits and the receiver receives data using hardware components, such as digital-to-analog or analog-to-digital converters, amplifiers, and antennas." (Dkt. No. 135, at 25.) For example, Defendants submit: "Prior to being transmitted, data can be interleaved by an interleaver to spread out the symbols of each codeword. The data, however, is not transmitted using the interleaver functionality." (*Id.*) Defendants argue that "[t]h[e] claims and specification excerpts [cited by Plaintiff] merely repeat the illogical proposition of transmitting/receiving using an interleaver/deinterleaver, which, as discussed above, does not sufficiently inform a POSITA about the scope of the term." (*Id.*, at 26.)

Plaintiff replies that Defendants' indefiniteness challenge lacks merit because "[i]t is undisputed that the Patents disclose that the transmitter performs interleaving and coding and,

conversely, the receiver performs deinterleaving and decoding." (Dkt. No. 140, at 9 (citing '348 Patent at 9:41–49).)

(b) Analysis

The claims here at issue involve transmitters and receivers, and the specification discloses for example:

> [W]hile some of the exemplary embodiments described herein are directed toward a transmitter portion of a transceiver performing interleaving and/or coding on transmitted information, it should be appreciated that a corresponding deinterleaving and/or decoding is performed by a receiving portion of a transceiver. Thus, while perhaps not specifically illustrated in every example, this disclosure is intended to include this corresponding functionality in both the same transceiver and/or another transceiver.

'348 Patent at 9:41–49.

Claim 1 of the '348 Patent, for example, recites (emphasis added):

> 1. An apparatus comprising:
> a multicarrier transceiver including a processor and memory operable to:
> transmit a packet using a forward error correction encoder and an interleaver, wherein the packet comprises a header field and a plurality of PTM-TC codewords, a plurality of ATM cells or a plurality of Reed-Solomon codewords, and wherein the header field comprises a sequence identifier (SID); and
> *receive a plurality of messages using a forward error correction decoder and without using a deinterleaver*, wherein each message of the plurality of messages is received in a different DMT symbol and wherein at least one message of the plurality of messages includes an acknowledgement (ACK) or a negative acknowledgement (NACK) of the transmitted packet.
>
> * * *
>
> 3. The apparatus of claim 1, wherein the transceiver is operable to retransmit the packet using the forward error correction encoder and the interleaver.

These claims expressly recite a "transceiver" that transmits and receives, and the recitals of using or not using an "interleaver" or a "deinterleaver" do not give rise to any lack of reasonable certainty regarding the scope of these claims. The other claims here at issue are

similar in this regard. Defendants argue that these claims are unclear because "interleaving and deinterleaving functionalities do not actually transmit or receive data." (Dkt. No. 135, at 25.) For example, Defendants argue that interleaving occurs *before* transmitting. Plaintiff's expert persuasively opines, however, that "[t]hese terms quite simply specify that functionality of a transceiver (transmitting, for example) is performed using a specified sub-function or sub-element of the transceiver (interleaving, for example)." (Dkt. No. 124, Ex. 12, Mar. 15, 2022 Cooklev Decl., at ¶¶ 146.) To whatever extent the opinions set forth in the declaration of Defendants' expert can be read as stating otherwise, those opinions of Defendants' expert are unpersuasive. (*See* Dkt. No. 135, Ex. 25, Mar. 14, 2022 Wesel Decl., at ¶¶ 50–56.)

The Court therefore hereby expressly rejects Defendants' indefiniteness arguments as to these disputed terms, and Defendants present no alternative proposed constructions.

The Court accordingly hereby construes these disputed terms to have their **plain meaning**.

XI. DISPUTED TERMS IN THE "FAMILY 10" PATENTS

Plaintiff submits that "the Family 10 Patents generally relate to assigning different signal-to-noise ('SNR') margins to different carriers to address the tradeoff between channel robustness and the available data rate." (Dkt. No. 124, at 1 (citation omitted).)

The '354 Patent, titled "Systems and Methods for a Multicarrier Modulation System with a Variable Margin," issued on October 6, 2015, and bears an earliest priority date of April 18, 2000. The Abstract of the '354 Patent states:

> A multicarrier modem has a plurality of carriers over which data is transmitted. By assigning, for example, one or more different margins to the individual carriers the data rate and impairment immunity can be increased.

33. "a multicarrier communications transceiver operable to: receive a multicarrier symbol comprising a first plurality of carriers"

"a multicarrier communications transceiver operable to: receive a multicarrier symbol comprising a first plurality of carriers" ’354 Patent, Claim 10	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Indefinite

(Dkt. No. 107, Ex. A, at 108; *id.*, Ex. B, at 17; Dkt. No. 146, App'x A, at 10–11; Dkt. No. 149, App'x A, at 70.)

(a) The Parties' Positions

Plaintiff argues that "[t]he specification teaches how multicarrier modulation is used to transmit bits using multiple carriers," and "[o]ne of ordinary skill would have understood that [*sic*] a multicarrier symbol that comprises a first plurality of carriers to refer to that multicarrier signal, viewed as the collection of bit st[r]eams from a digital perspective (e.g., the collection of bits on each carrier)." (Dkt. No. 124, at 27 (citations omitted).)

Defendants respond: "A multicarrier symbol in the context of a discrete multitone modulation system is the sum of the full collection of carriers modulated by the system. The intrinsic record of the ’354 Patent fails to inform a POSITA how a multicarrier symbol is subdivided into different subsets of carriers." (Dkt. No. 135, at 27–28 (citation and internal quotation marks omitted).)

Plaintiff replies that Defendants' argument "is not a definiteness argument (which is about understanding the scope of the claims); it is an incorrect written description or enablement argument." (Dkt. No. 140, at 10.)

(b) Analysis

Claim 10 of the '354 Patent (as corrected by two Certificates of Correction, *see* Dkt. No. 124, Ex. 10, at pp. 11–12 of 12) recites (emphasis added):

> 10. *A multicarrier communications transceiver operable to:*
> *receive a multicarrier symbol comprising a first plurality of carriers* and a second plurality of carriers;
> receive a first plurality of bits on the first plurality of carriers using a first SNR margin;
> receive a second plurality of bits on the second plurality of carriers using a second SNR margin;
> wherein the first plurality of carriers is different than the second plurality of carriers,
> wherein the first SNR margin is different than the second SNR margin, and
> wherein the first SNR margin provides more robust reception than the second SNR margin.

Defendants argue that "[t]he intrinsic record of the '354 Patent fails to inform a POSITA how a multicarrier symbol is subdivided into different subsets of carriers." (Dkt. No. 135, at 28.)

Plaintiff's expert opines that a "multicarrier symbol" is conveyed by a multicarrier signal, which can be "viewed as the collection of bit st[r]eams from a digital perspective (*e.g.*, the collection of bits on each carrier)." (Dkt. No. 124, Ex. 12, Mar. 15, 2022 Cooklev Decl., at ¶ 151.)

The specification supports this understanding by disclosing that carriers are used "collectively" to convey data:

> Multicarrier modulation, or Discrete Multitone Modulation (DMT), is a transmission method that is widely used for communication over difficult media. Multicarrier modulation divides the transmission frequency band into multiple subchannels, i.e., carriers or bins, with each carrier individually modulating a bit or a collection of bits. A transmitter modulates an input data stream containing information bits with one or more carriers, i.e., bins or subchannels, and transmits the modulated information. A receiver demodulates all the carriers in order to recover the transmitted information bits as an output data stream.
>
> * * *

> Individually, the carriers form discrete, non-overlapping communication subchannels which are of a limited bandwidth. Collectively, the carriers form what is effectively a broadband communications channel. At the receiver end, the carriers are demodulated and the data recovered.

'354 Patent at 1:32–43 & 3:8–13; *see also id.* at Abstract ("A multicarrier modem has a plurality of carriers over which data is transmitted.").

This understanding is also consistent with the context in which the disputed term appears in the claim (reproduced above), wherein a "multicarrier symbol" conveys "a first plurality of bits on the first plurality of carriers" and "a second plurality of bits on the second plurality of carriers." Thus, "multicarrier symbol" can be understood as conveying bits by using multiple carriers. This is by no means the only requirement set forth by the claim, but the Court rejects Defendants' argument that this requirement is not reasonably clear in the context of the claim and the specification.

The opinions of Defendants' expert are likewise unpersuasive. (*See* Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl. at ¶¶ 83–86.) Defendants' expert opines:

> The specification of the '354 Patent does not disclose or define a "multicarrier symbol." The specification shows that the alleged invention relates to a discrete multitone modulation system. *See, e.g.*, '354 Patent at 1:30–2:45, 4:14–16 ("In an exemplary embodiment of the invention, the margin is set to be different on at least two subchannels in a discrete multitone modulation system."). Therefore, in this context, a person of ordinary skill in the art would understand a "multicarrier symbol" to refer to a symbol used in a discrete multitone modulation system, which is the sum of the full collection of carriers modulated by the system. It is unclear to a person of ordinary skill in the art how a multicarrier symbol is subdivided into a first and a second plurality of carriers. Furthermore, it is unclear to a person of ordinary skill in the art how a multicarrier symbol could comprise a subset of carriers from the full collection such that there could be a first plurality of carriers and a second plurality of carriers.

(*Id.* at ¶ 84.) Defendants' expert thus agrees that "a person of ordinary skill in the art would understand a 'multicarrier symbol' to refer to a symbol used in a discrete multitone modulation

system, which is the sum of the full collection of carriers modulated by the system." (*Id.*) The opinions that "[i]t is unclear to a person of ordinary skill in the art how a multicarrier symbol is subdivided into a first and a second plurality of carriers" and "it is unclear to a person of ordinary skill in the art how a multicarrier symbol could comprise a subset of carriers from the full collection such that there could be a first plurality of carriers and a second plurality of carriers" (*id.*) do not demonstrate indefiniteness but rather perhaps may bear upon enablement or written description requirements, which are not at issue in the present claim construction proceedings. *See Phillips*, 415 F.3d at 1327 ("we have certainly not endorsed a regime in which validity analysis is a regular component of claim construction") (citation omitted).

The Court therefore hereby expressly rejects Defendants' indefiniteness argument as to this disputed term. Defendants present no alternative proposed construction, and no further construction is necessary.

The Court accordingly hereby construes **"a multicarrier communications transceiver operable to: receive a multicarrier symbol comprising a first plurality of carriers"** to have its **plain meaning**.

34. "receive a first plurality of bits on the first plurality of carriers using a first SNR margin; receive a second plurality of bits on the second plurality of carriers using a second SNR margin"

"receive a first plurality of bits on the first plurality of carriers using a first SNR margin; receive a second plurality of bits on the second plurality of carriers using a second SNR margin" '354 Patent, Claim 10	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Indefinite

(Dkt. No. 107, Ex. A, at 108; *id.*, Ex. B, at 17; Dkt. No. 146, App'x A, at 11; Dkt. No. 149, App'x A, at 71.)

(a) The Parties' Positions

Plaintiff argues that "[t]he Patent explains that the SNR margin is used to determine the number of bits to allocate to each carrier," "[t]he margin is set on each carrier," and "[t]hus, receiving bits on carriers 'using a [first/second] SNR margin' is reasonably understood to mean that the claimed multicarrier transceiver is operable to receive bits on a carriers [*sic*] where an SNR margin is used for performing bit loading on the carriers." (Dkt. No. 124, at 28 (citations omitted).)

Defendants respond that "the language of claim 10 of the '354 Patent is directed to receiving information bits," and "[b]y contrast, bit loading is performed with the *transmitter* portion of the transceiver—not the receiver portion." (Dkt. No. 135, at 28 (emphasis added).) "Therefore," Defendants argue, "it is unclear to a POSITA how the transceiver is operable to *receive* a [first/second] plurality of bits *using* an SNR margin." (*Id.*) Further, Defendants argue, "assigning different SNR margins, as described in the '354 Patent specification and discussed in TQ Delta's opening brief, fails to describe *how* the SNR Margin is used to 'receive' a [first/second] plurality of bits." (*Id.*, at 28–29 (citations omitted).)

Plaintiff replies that "the Patents explain that . . . the language refers to receiving bits on carriers where an SNR margin was used to perform bit loading . . . ." (Dkt. No. 140, at 10 (citing Dkt. No. 124, at 28–29).) Plaintiff argues that Defendants' argument "is a misplaced written description or enablement argument, not a definiteness challenge." (*Id.*)

(b) Analysis

Claim 10 of the ’354 Patent (as corrected by two Certificates of Correction, *see* Dkt. No. 124, Ex. 10, at pp. 11–12 of 12) recites (emphasis added):

> 10. A multicarrier communications transceiver operable to:
> receive a multicarrier symbol comprising a first plurality of carriers and a second plurality of carriers;
> *receive a first plurality of bits on the first plurality of carriers using a first SNR margin;*
> *receive a second plurality of bits on the second plurality of carriers using a second SNR margin*;
> wherein the first plurality of carriers is different than the second plurality of carriers,
> wherein the first SNR margin is different than the second SNR margin, and
> wherein the first SNR margin provides more robust reception than the second SNR margin.

Defendants argue that this disputed term is unclear because whereas these claim limitations are directed to *receiving* a communication, "using" an SNR margin occurs when *transmitting*. Defendants' expert opines:

> During initialization of the discrete multitone modulation system, the signal-to-noise ratios of each subchannel is calculated by the system by sending signals between the transmitter and receiver. Then, the system calculates the number of bits that can be transmitted on each subchannel, in part, by using the calculated signal-to-noise ratios of each subchannel. A person of ordinary skill in the art would not understand how the transmitter could "receive a [first/second] plurality of bits . . . using a [first/second] SNR margin" when the SNR margin is used by the transmitter during initialization to determine the number of bits to transmit on each subchannel. Nor could a person of ordinary skill in the art understand how the SNR margin, as assigned to the plurality of carriers, is used to "receive a [first/second] plurality of bits." Based on the ’354 Patent specification, a person of skill in the art would understand that the SNR margin is assigned to the plurality of carriers based on impairments of or on a carrier, such as insertion loss of the wire or medium itself, or based on a known impairment on a carrier. *See* ’354 Patent at 2:14–19; 5:3–6; 7:29–36. Accordingly, the SNR margin is not used to receive a plurality of bits.

(*See* Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl. at ¶ 89.)

A fair reading of the claim language, however, is that the "receive . . ." limitations refer to receiving a transmission *from* a transmitter that is operable to transmit, for example, a first plurality of bits on the first plurality of carriers using a first SNR margin. This understanding is consistent with disclosures in the specification, such as disclosure regarding signal-to-noise ratio ("SNR") margins specifying an amount of "extra" SNR for a transmission:

> Discrete multitone modulation transceivers modulate a number of bits on each subchannel, the number of bits depending on the Signal to Noise Ratio (SNR) of that sub channel and the Bit Error Rate (BER) requirement of a link. For example, if the required BER is $1x10^{-7}$, i.e., one bit in ten million is received in error on average, and the SNR of a particular subchannel is 21.5 dB, then that subchannel can modulate 4 bits, since 21.5 dB is the required SNR to transmit 4 QAM bits with a $1x10^{-7}$ BER. Other subchannels can have a different SNR and therefore may have a different number of bits allocated to them at the same BER. Additional information regarding bit loading can be found in copending U.S. application Ser. No. 09/510,773, incorporated herein by reference in its entirety.
>
> In many DMT systems, an additional parameter is used to determine the number of bits allocated to each subchannel. This parameter is called the ["]SNR []margin," or simply the "margin." The margin specifies an extra SNR per subchannel, in addition to what is required to maintain the specified BER requirement. As an example, a DMT system with a 6 dB margin would require a 21.5+6=27.5 dB SNR on a subchannel in order to transmit 4 bits on that subchannel with a $1x10^{-7}$ BER. This is 6 dB more than required by the example in the previous paragraph because now a 6 dB margin is added to the system. Another way of looking at this is that in the example of the previous paragraph, where 4 bits were allocated to a subchannel with 21.5 dB SNR, the margin was 0 dB.
>
> * * *
>
> In an exemplary embodiment of the invention, the margin is set to be different on at least two subchannels in a discrete multitone modulation system. In this exemplary embodiment, subchannels which are expected to incur greater variations in impairment levels are set to have a higher margin, whereas subchannels which are expected to incur lower variations in impairment levels are set to have lower margins.

'354 Patent at 1:57–2:17 & 4:14–20.

Particularly when reading the claim language in light of this disclosure in the specification, the limitation of "receive a first plurality of bits on the first plurality of carriers using a first SNR margin," for example, is readily understood not as referring to using the SNR margin to receive the bits, as Defendants suggest, but rather as referring to receiving carriers that were transmitted using a particular SNR margin.

The Court therefore hereby expressly rejects Defendants' indefiniteness argument as to this disputed term, and Defendants present no alternative proposed construction.

The Court accordingly hereby construes **"receive a first plurality of bits on the first plurality of carriers using a first SNR margin; receive a second plurality of bits on the second plurality of carriers using a second SNR margin"** to have its **plain meaning**.

35. "wherein the first SNR margin provides more robust reception than the second SNR margin"

"wherein the first SNR margin provides more robust reception than the second SNR margin" '354 Patent, Claim 10	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	Indefinite

(Dkt. No. 107, Ex. A, at 109; *id.*, Ex. B, at 17; Dkt. No. 146, App'x A, at 11; Dkt. No. 149, App'x A, at 72.)

<u>(a) The Parties' Positions</u>

Plaintiff argues that "[t]he Patent describes 'robustness' in the context of the SNR margin for a channel as allowing the system to maintain a required bit error rate," and "[t]hus, one of ordinary skill would have understood that the first signal-to-noise ('SNR') margin provides more

robust reception than the second SNR margin by, for example, reducing the bit error rate (e.g., making it less likely that a transmission would be subject to significant errors, which makes the reception more 'robust,' e.g., less likely to require error correction or retransmission)." (Dkt. No. 124, at 29 (citations omitted).)

Defendants respond: "TQ Delta and its own expert acknowledge that the '354 Patent specification describes robustness only as a measurement of the overall system. Not only does the specification fail to describe *how* an SNR margin (at the carrier level) provides more robust reception at the system level, but it also fails to describe how the SNR Margin, as opposed to other known factors, *provides* more robust reception." (Dkt. No. 135, at 29 (citations omitted).)

Plaintiff replies that "robustness refers to maintaining a required bit-error rate." (Dkt. No. 140, at 10 (citing Dkt. No. 124, at 28–29).) Plaintiff argues that Defendants' argument "is a misplaced written description or enablement argument, not a definiteness challenge." (*Id.*)

<u>(b) Analysis</u>

Claim 10 of the '354 Patent (as corrected by two Certificates of Correction, *see* Dkt. No. 124, Ex. 10, at pp. 11–12 of 12) recites (emphasis added):

> 10. A multicarrier communications transceiver operable to:
> receive a multicarrier symbol comprising a first plurality of carriers and a second plurality of carriers;
> receive a first plurality of bits on the first plurality of carriers using a first SNR margin;
> receive a second plurality of bits on the second plurality of carriers using a second SNR margin;
> wherein the first plurality of carriers is different than the second plurality of carriers,
> wherein the first SNR margin is different than the second SNR margin, and
> *wherein the first SNR margin provides more robust reception than the second SNR margin*.

Defendants' expert opines that this disputed term is unclear because "[t]he specification refers to robustness as a tradeoff with data rate for the whole system, not individual carriers." (Dkt. No. 135, Ex. 24, Mar. 14, 2022 Zimmerman Decl. at ¶ 93 (citing '354 Patent at 2:17–33 (reproduced below)).) "Moreover," Defendants' expert opines, "'robustness' of a signal can be measured in a number of different ways," and "[t]he specification lists some of these as advantages of multicarrier modulation, for example, 'a higher immunity to impulse noise, a lower complexity equalization requirement in the presence of multipath, a higher immunity to narrow band interference, a higher data rate and bandwidth flexibility.'" (*Id.*, at ¶ 94 (citing '354 Patent at 1:45–49).)

The specification provides context for the recital of "robust" by disclosing:

> DMT transceivers use a margin to increase the system's immunity to various types of time varying impairments. Examples of these impairments in DSL systems are: changes in the levels of crosstalk from other transmission systems, impulse noise, temperature changes in the telephone line, or the like. When a DMT system is operating with a positive SNR margin, the noise can change instantaneously by the level of the margin and the system will still maintain the required BER. For example, if the system is operating at a 6 dB margin, e.g., 4 bits are allocated to carriers with 27.5 dB SNR for BER=$1x10^{-7}$, the crosstalk levels can increase by 6 dB and the system will still be operating at the required $1x10^{-7}$ BER. Obviously the penalty for this *increase in robustness* is a decrease in the data rate, since with a 0 dB margin, a subchannel with 27.5 dB SNR can modulate 6 bits at $1x10^{-7}$ BER.
>
> Therefore, there is a tradeoff between the *robustness* of the channel. Such as a phone line, and the achievable data rate. The margin can be used to quantify this tradeoff. A *higher margin* results in a higher level of immunity to changing channel conditions at the expense of the achievable data rate. Likewise, a lower margin results in a higher data rate at the expense of a lower immunity to changing channel conditions.

'354 Patent at 2:18–40 (emphasis added); *see id.* at 3:34–51 (similar).

This disclosure regarding using increased SNR to achieve an "increase in robustness" provides context for understanding that "the first SNR margin provides more robust reception

than the second SNR margin" by the first SNR margin being greater in magnitude than the second SNR margin. *See id.* at 2:18–40. Although perhaps this is not the only way to increase "robustness," the claim here at issue expressly refers to using SNR margin, and the specification explains that a greater SNR margin provides increased robustness. *See id.*

The Court therefore hereby construes **"wherein the first SNR margin provides more robust reception than the second SNR margin"** to mean **"wherein the first SNR margin is greater than the second SNR margin."**

36. "signal to noise ratio (SNR) margin" and "SNR margin"

"signal to noise ratio (SNR) margin" **"SNR margin"** '988 Patent, Claim 16 '354 Patent, Claim 10	
Plaintiff's Proposed Construction	**Defendants' Proposed Construction**
Plain and ordinary meaning. No construction necessary.	"a parameter used in determining the number of bits allocated to each of a plurality of carriers, where the value of the parameter specifies an extra SNR requirement assigned per carrier in addition to the SNR required to maintain a specified bit error rate (BER) for the communication link at a specified bit allocation"

(Dkt. No. 107, Ex. A, at 110; *id.*, Ex. B, at 18; Dkt. No. 146, App'x A, at 11; Dkt. No. 149, App'x A, at 73.)

(a) The Parties' Positions

Plaintiff argues that "SNR margin is an established term to those of skill in the art, referencing 'an additional parameter' in multicarrier systems that is 'used to determine the number of bits allocated to each subchannel.'" (Dkt. No. 124, at 30 (quoting '354 Patent at 2:4–

5).) Plaintiff also urges that "[w]hile [in prior litigation] TQ Delta agreed to the same construction proposed by Defendants' here," "TQ Delta submits that Defendants' proposed construction is unlikely to assist the jury to resolve any fact issues any more than the simpler term 'SNR margin' (which, again, is an established term in the multicarrier communications art)." (*Id.* (citation omitted).)

Defendants respond that "Defendants' proposal finds direct support in the shared specification of the '354 and '988 Patents (*see* '354 Patent at 2:4–9), and TQ Delta previously agreed to the same construction in the ADTRAN Case." (Dkt. No. 135, at 30 (citation omitted).)

Plaintiff replies: "Defendants fail to identify any claim-scope issue. There is no need to construe this term." (Dkt. No. 140, at 10.)

(b) Analysis

Defendants propose a construction that Plaintiff agreed to in the District of Delaware as to United States Patent No. 8,625,660 ("the '660 Patent"), which is a "grandparent" of the '354 Patent. Specifically, the '354 Patent resulted from a continuation of a continuation of the '660 Patent. The District of Delaware adopted an agreement reached between the parties in that case to construe "signal to noise ratio (SNR) margin" to mean "a parameter used in determining the number of bits allocated to each of a plurality of carriers, where the value of the parameter specifies an extra SNR requirement assigned per carrier in addition to the SNR required to maintain a specified bit error rate (BER) for the communication link at a specified bit allocation." *TQ Delta, LLC v. ADTRAN, Inc.*, No. 1:14-CV-00954-RGA, Dkt. No. 375, slip op. at 5 (D. Del. Apr. 27, 2018).

This construction that was agreed upon as to the related '660 Patent in the District of Delaware is consistent with disclosure in the specification:

> In many DMT [(Discrete Multitone Modulation)] systems, an additional parameter is used to determine the number of bits allocated to each subchannel. This parameter is called the SNR "margin," or simply the "margin." The margin specifies an extra SNR per subchannel, in addition to what is required to maintain the specified BER [(Bit Error Rate)] requirement.

'354 Patent at 2:4–9. The construction agreed upon in the District of Delaware is supported by this disclosure, and "some construction of the disputed claim language will assist the jury to understand the claims." *TQP Dev., LLC v. Merrill Lynch & Co.*, No. 2:08-CV-471, 2012 WL 1940849, at *2 (E.D. Tex. May 29, 2012) (Bryson, J., sitting by designation).

Finally, Plaintiff does not substantively oppose Defendants' proposal of the construction that Plaintiff agreed upon in the District of Delaware as to the related '660 Patent. Instead, Plaintiff states that "SNR margin is an established term to those of skill in the art, referencing 'an additional parameter' in multicarrier systems that is 'used to determine the number of bits allocated to each subchannel,' and "[i]t is unclear if there is a claim-scope dispute between the parties for these terms." (Dkt. No. 124, at 30 (quoting '354 Patent at 2:4–9).)

The Court therefore adopts the construction agreed upon in the District of Delaware. This comports with the general principle that "[w]here multiple patents 'derive from the same parent application and share many common terms, we must interpret the claims consistently across all asserted patents.'" *SightSound Techs., LLC v. Apple Inc.*, 809 F.3d 1307, 1316 (Fed. Cir. 2015) (quoting *NTP, Inc. v. Research In Motion, Ltd.*, 418 F.3d 1282, 1293 (Fed. Cir. 2005), and applying the same construction for a claim term appearing in the claims of multiple related patents). Also, the claims at issue in the present case, like the claims at issue in the construction by the District of Delaware in a related patent, use SNR margin in the context of pluralities of bits and pluralities of carriers. *See* '988 Patent, Cl. 16; *see also* '354 Patent, Cl. 10. Because this

Court adopts the Delaware construction, the Court need not reach Defendants' argument that Plaintiff is estopped from proposing a different construction.

The Court accordingly hereby construes **"Signal to Noise Ratio (SNR) margin"** to mean **"a parameter used in determining the number of bits allocated to each of a plurality of carriers, where the value of the parameter specifies an extra SNR requirement assigned per carrier in addition to the SNR required to maintain a specified bit error rate (BER) for the communication link at a specified bit allocation."**

XII. CONCLUSION

The Court adopts the constructions set forth in this opinion for the disputed terms of the patents-in-suit.

The parties are ordered that they may not refer, directly or indirectly, to each other's claim construction positions in the presence of the jury. Likewise, the parties are ordered to refrain from mentioning any portion of this opinion, other than the actual definitions adopted by the Court, in the presence of the jury. Any reference to claim construction proceedings is limited to informing the jury of the definitions adopted by the Court.

So ORDERED and SIGNED this 8th day of June, 2022.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC, *Plaintiff*, v. COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS US HOLDINGS, INC., ARRIS SOLUTIONS, INC., ARRIS TECHNOLOGY, INC., and ARRIS ENTERPRISES, LLC, *Defendants*.	§ § § § § § § § § § § § § § §	CIVIL ACTION NO. 2:21-CV-00310-JRG

ORDER ON PRETRIAL MOTIONS AND MOTIONS *IN LIMINE*

The Court held a Pretrial Conference in the above-captioned case on Wednesday, March 1, 2023 (Dkt. No. 482), and Thursday, March 2, 2023 (Dkt. No. 486), regarding pending pretrial motions and motions *in limine* ("MILs") filed by Plaintiff TQ Delta, LLC ("TQ Delta") and Defendants CommScope Holding Company, Inc., CommScope Inc., ARRIS International Limited, ARRIS Global Ltd., ARRIS US Holdings, Inc., ARRIS Solutions, Inc., ARRIS Technology, Inc., and ARRIS Enterprises, LLC (collectively, "CommScope"). (*See* Dkt. Nos. 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 349, 451, 452). This Order memorializes the Court's rulings on the pretrial motions, MILs, and disputed exhibits as announced from the bench into the record, including additional instructions that were given to the parties and certain agreements and stipulations reached by the parties as announced into the record. Although this Order summarizes the Court's rulings as announced into the record during the Pretrial Conference, this Order in no

way limits or constrains such rulings from the bench as reflected in the record. Accordingly, it is hereby **ORDERED** as follows:

PRETRIAL MOTIONS

1. TQ Delta's Motion for Summary Judgment of No Breach of Any FRAND Obligations (Family 3 and Family 9A Non-Essential Patents) (Dkt. No. 335)

The motion was **GRANTED**. (Dkt. No. 493 at 263:14–264:4). The Court concluded, and the parties did not dispute, that U.S. Patent Nos. 7,844,882 (the "'882 Patent") and 8,276,048 (the "'048 Patent") of Patent Family 3 as well as U.S. Patent No. 8,468,411 (the "'411 Patent") of Patent Family 9a are not standard essential patents.

2. CommScope's Motion for Summary Judgment of Non-Infringement of the Family 3 Patents (Dkt. No. 336)

The motion was **DENIED**. (Dkt. No. 493 at 156:7–12). The Court found that there remains a triable question of fact that precludes the grant of summary judgment under Federal Rule of Civil Procedure 56.

3. TQ Delta's Motion to Strike the Expert Testimony of Dr. George A. Zimmerman, Dr. Richard Wesel, Dr. Bruce McNair, and Dr. Niel Ransom (Dkt. No. 337)

The motion was **DENIED**. (Dkt. No. 493 at 218:7–221:12). As to the first issue regarding background information, the Court held that CommScope is entitled during trial to show during trial what the background of the prior art and what would be understood by a person of ordinary skill in the art. (*Id.* at 218:7–219:20). However, such use is for background purposes and not as a backdoor effort for CommScope to establish that every element of the asserted claim is set forth within the elected prior art. (*Id.*). With regard to issue two, the parties conceded that the written description portion of the motion is no longer in dispute. (*Id.* at 219:20–22). For issue three, the Court observed that it does not expect Drs. Vijay Madisetti or Niel Ransom to testify contrary to

the Court's claim construction and that any contrary effort can be addressed in real time with an appropriate objection. (*Id.* at 219:23–221:12).

4. TQ Delta's Motion to Strike the Invalidity Report of Defendants' Expert, Mark Lanning (Dkt. No. 338)

The motion was **GRANTED-IN-PART and DENIED-IN-PART**. (Dkt. No. 493 at 178:10–179:7). The Court **GRANTED** the motion as to striking paragraphs 23 and 1068 of Mr. Mark Lanning's opening expert report given that reference to the TNETD8000 User Guide related only to a patent that has been dropped from the case. The Court further struck all portions of Mr. Lanning's report that rely on or present any opinion related to the Peeters or Cai references in light of CommScope's representation that such portions of his opinion have been withdrawn. The Court found that Mr. Lanning's report did not contradict or fail to apply the Court's construction of SNR margin and **DENIED** the motion as to that issue.

5. TQ Delta's Motion to Strike Portions of the Non-infringement Report and Opinions of Defendants' Expert, Dr. Leonard J. Cimini, Jr. (Dkt. No. 339)

The motion was **GRANTED**. (Dkt. No. 494 at 4:4–5:12). The Court struck paragraphs 80 through 87 of Dr. Cimini's responsive expert report. The Court concluded that Dr. Cimini applied three different constructions or understandings of the claim term "transmit from the transceiver a diagnostic message using multicarrier modulation with DMT symbols that are mapped to one bit of the diagnostic message," and noted that any expert, including Dr. Cimini, must use the same theories and positions for both infringement and invalidity, which here, Dr. Cimini failed to do.

6. CommScope's Motion for Partial Summary Judgment to Limit Damages Based on 35 U.S.C. § 286 (Dkt. No. 340)

The motion was **DENIED**. (Dkt. No. 493 at 66:5–8). The Court concluded that there are questions of material fact that preclude the entry of summary judgment.

7. TQ Delta's Motion to Strike Portions of the Non-infringement Report and Opinions of Defendants' Expert, Dr. Naofal Al-Dhahir (Dkt. No. 341)

The motion was **GRANTED**. (Dkt. No. 493 at 235:9–236:14). The Court struck paragraphs 209 through 214 of Dr. Naofal Al-Dhahir's responsive expert report and found that CommScope failed to timely and properly disclose non-infringing alternatives during the discovery period in response to an appropriate interrogatory request.

8. CommScope's Motion to Exclude Certain Unreliable Opinions of Plaintiff's Expert Dr. Vijay Madisetti (Dkt. No. 342)

The motion was **GRANTED-IN-PART and DENIED-IN-PART**. (Dkt. No. 493 at 196:15–197:4). The Court struck paragraphs 69 through 72 of Dr. Madisetti's rebuttal expert report because they conflicted with the Court's claim construction. However, the Court declined to strike paragraph 73 but instructed TQ Delta that Dr. Madisetti is prohibited from providing any opinion contrary to the Court's claim constructions and that he and all expert witnesses must stay within the four corners of their reports.

9. CommScope's Motion for Partial Summary Judgment Regarding Prior Art Status (Dkt. No. 343)

The motion was **GRANTED**. (Dkt. No. 494 at 213:23–214:1). In light of TQ Delta's prior admissions in the District of Delaware, this Court found that the G.993.1, LB-031, G.992.1, and SC-060 references are prior art pursuant to 35 U.S.C. § 102(a) (pre-AIA).

10. CommScope's Motion to Exclude Portions of the Expert Testimony of Jonathan Putnam and Todor Cooklev Under Fed. R. Evid. 702 and Daubert (Dkt. No. 344)

The motion was **DENIED**. (Dkt. No. 493 at 106:6–12). The Court found that robust cross-examination is adequate to address the issues raised by CommScope and that exclusion is not justified.

11. TQ Delta's Motion to Strike Portions of the Expert Report of Stephen L. Becker, Ph.D. (Dkt. No. 345)

The motion was **GRANTED-IN-PART and DENIED-IN-PART**. (Dkt. No. 493 at 141:16–142:23). The Court **DENIED** the motion as to the smallest saleable patent practicing unit (SSPPU) and concluded that Dr. Becker sufficiently relied on technical experts' opinions to adequately discern the SSPPU in his expert report. The Court **GRANTED** the motion with regard to using the Sisvel Agreements and Rate Card as an independent check on his ultimate opinions and struck paragraphs 199 through 205, 233, 315 through 317 and Exhibit 12 of Dr. Becker's expert report.

12. CommScope's Motion to Exclude Expert Testimony of Jonathan Putnam, Ph.D. that Is Inconsistent with Legal Precedent (Dkt. No. 346)

The motion was **GRANTED-IN-PART and DENIED-IN-PART**. (Dkt. No. 493 at 97:22–100:5). During argument, the Court identified five distinct subparts of this motion. For issue one, the Court **DENIED** the motion and held that in light of paragraph 378 of Dr. Putnam's expert report, he has limited his opinion to a subset of standard essential patent families within the entire DSL standard. (*Id.* at 98:2–8). For issue two, the Court **DENIED** the motion and held that the SSPPU is not the only possible metric in calculating apportionment. (*Id.* at 98:9–13). With regard to issue three, the motion was **GRANTED-IN-PART**, and the Court precluded Dr. Putnam from using the Nash Bargaining Theory in his testimony; however, it noted that he is not precluded from presenting other information that supports the same conclusion or reaches the same result. (*Id.* at 98:14 –99:6). As to issue four and Dr. Putnam's opinion on the hypothetical negotiation date, the Court **DENIED** the motion. (*Id.* at 99:7–14). As to issue five, the Court **DENIED** the motion and concluded that it is appropriate to discount the value of comparable license agreements to account for the uncertainty of questions as to validity or infringement. (*Id.* at 99:15–22).

13. TQ Delta's Motions for Summary Judgment Directed to Patent Families 1 and 10 (Dkt. No. 347)

The was motion was **DENIED**. (Dkt. No. 494 at 214:2–5). During oral argument, TQ Delta identified three sub-parts of its motion. For issue three, as to no invalidity of Patent Family 10, TQ Delta conceded that it could not succeed on the merits based on the Court's ruling on TQ Delta's Motion to Strike the Invalidity Report of Defendants' Expert, Mark Lanning (Dkt. No. 338). (Dkt. No. 494 at 204:3–8). Regarding issues one and two, the Court **DENIED** the motion and found that there are outstanding questions of material fact, which preclude summary judgment.

14. TQ Delta's Opposed Motion for Leave to Formally Serve the First Supplemental Expert Report of Jonathan D. Putnam on the CommScope Defendants (Dkt. No. 349)

The motion was **GRANTED**. (Dkt. No. 493 at 66:9–11). The Court permitted TQ Delta leave to serve CommScope with Dr. Putnam's First Supplemental Report. Under these facts, the Court found that leave was warranted.

MOTIONS *IN LIMINE*

It is **ORDERED** that the parties, their witnesses, and counsel shall not raise, discuss, or argue the following before the venire panel or the jury without prior leave of the Court:

I. TQ DELTA'S OPPOSED MOTIONS *IN LIMINE* (Dkt. No. 451)

TQ Delta's MIL 1	**Precluding presentation or argument that TQ Delta or its predecessor-in-interest violated any rule or policy of, or agreement with, any standards body (e.g., ITU or ANSI) by, for example, failing to disclose any specific patent or patent application number to the standards body, or by failing to disclose in a timely manner that it believes it holds any standard essential patent or patent application (e.g., by filing a patent statement and licensing declaration).**

The MIL was **GRANTED-AS-MODIFIED**. (Dkt. No. 494 at 8:9–9:1). With the parties' assent, the Court removed the words "for example" from the parties' otherwise agreed MIL, which now provides as follows: "Precluding presentation or argument that TQ Delta or its predecessor-in-

interest violated any rule or policy of, or agreement with, any standards body (e.g., ITU or ANSI) by failing to disclose any specific patent or patent application number to the standards body, or by failing to disclose in a timely manner that it believes it holds any standard essential patent or patent application (e.g., by filing a patent statement and licensing declaration)." (*Id.* at 6:24–7:7).

TQ Delta's MIL 2	**Precluding reference to and presentation of any argument, evidence, and testimony relating to: (a) TQ Delta, LLC's business model and corporate structure as being suspicious or improper; (b) Other entities that are or that are insinuated to be associated with TQ Delta, LLC such as but not limited to Techquity LP, TQCAP GP, LLC, Techquity Capital Management, LLC, and entities owned, in whole or in part, or managed by them ("Other Entities"), including the identity and number of, and compensation paid to, the Other Entities' personnel; and (c) Investors or members in TQ Delta and the Other Entities, including their identities, capital contributions, ownership stake, and payments received, if any.**

The MIL was **GRANTED**. (Dkt. No. 494 at 11:7–16:9). The Court addressed each sub-part in turn. For sub-part (a), the Court observed that no numerical limit on the use of "non-practicing entity" at trial would be imposed, but the Court noted that excessive use of such term would be restricted. For sub-part (b), the Court held that the probative value of going into TQ Delta's corporate structure is outweighed by the prejudicial risk and effect of jury confusion. For sub-parts (b) and (c), it noted that while CommScope is not prohibited from addressing a witness's potential bias as to a particular interest in an entity related to TQ Delta, such examination must be addressed and approved on a case-by-case basis with prior leave of the Court.

<u>TQ Delta's MIL 3</u>	**Precluding presentation or argument that TQ Delta, its predecessor-in-interest, or the inventors were aware of prior art (of any kind under 35 U.S.C. § 102) but withheld or failed to disclose it to the Patent Office.**

The MIL was **DENIED** in light of CommScope's representations on the record: "[CommScope is] not going to say anything about inequitable conduct[,] . . . accuse anybody of intentionally deceiving or withholding something from the PTO[,] but through the course of what actually happened at the ITU[,] we do expect to go through some documents showing different parties' contributions." (Dkt. No. 494 at 17:14–22).

<u>TQ Delta's MIL 4</u>	**Precluding presentation comparing TQ Delta's requested royalty with CommScope's costs or profits from the Accused Products, including comparison to a claimed profit margin for the Accused Products.**

The MIL was **DENIED**. (Dkt. No. 494 at 20:20–21:6). However, the Court advised that its ruling does not limit TQ Delta's ability to raise an appropriate and individualized objections based on the rules of evidence and the Court's orders if and when such issues arise.

<u>TQ Delta's MIL 5</u>	**Precluding presentation or argument that the Accused Products must be actually operated or used in a particular mode (e.g., to provide DSL service or in a G.inp or G.bond mode) in order to infringe or in order to determine the appropriate amount of damages.**

The MIL was **DENIED**. (Dkt. No. 494 at 31:18–32:24). The Court held that CommScope is permitted to go into those topics identified in the MIL related to damages but not as to infringement. The Court **DENIED** the MIL based on representations by CommScope on the record: "[CommScope is] not going to argue that [it] do[es] not infringe because a product is not used in a particular mode. [CommScope] do[es] think that use, whether someone uses a particular mode is relevant to determine the appropriate amount of damages." (*Id.* at 28:9–13). The Court advised that it expects all expert witnesses to testify within the four corners of their reports, and it will take

up any such objections when appropriately raised. The Court also cautioned the parties about strategic uses of this type of objection.

TQ Delta's MIL 6	**Requested Clarification on Court's MIL No. 13: "The parties shall be precluded from introducing evidence, testimony, or argument regarding either party's other litigations or arbitrations, including parallel proceedings in any other court, tribunal, or forum, including ADR proceedings."**

The MIL was **DENIED**. (Dkt. No. 494 at 34:18–38:15). The Court rejected TQ Delta's proposed alternatives to the Court's MIL No. 13 and highlighted that the Court's MIL No. 13 precludes references to other litigation. As an example, and not a limitation, the Court made it clear that references to any aspect of the Delaware litigation is precluded unless express prior leave is granted.

II. COMMSCOPE'S OPPOSED MOTIONS *IN LIMINE* (Dkt. No. 452)

CommScope's MIL 1	**USE OF THE TERMS "HOLDOUT," "HOLDUP," AND "UNWILLING LICENSEE"**

The MIL was **DENIED**. (Dkt. No. 494 at 42:1–19). The Court noted that the identified terms in the MIL are live issues within the case; however, the Court advised that excessive use of such terms is not permitted.

CommScope's MIL 2	**PRIVILEGED TESTIMONY FROM MARCOS TZANNES.**

The MIL was **DENIED**. (Dkt. No. 494 at 49:22–50:10). The Court advised the parties that it will take up related objections on an individualized basis.

CommScope's MIL 3	**TESTIMONY CONTRARY TO TQ DELTA'S 30(B)(6) TESTIMONY.**

The MIL was **DENIED**. (Dkt. No. 494 at 58:17–63:16). The Court prohibited testimony by witnesses at trial (1) on information that was not disclosed during discovery because of an

asserted lack of knowledge and (2) on topics that were asserted as privileged. The Court noted that if an inventor is not a Rule 30(b)(6) witness, said inventor's testimony will be limited to what he or she has personal knowledge of and any testimony given at deposition.

CommScope's MIL 4	**OFFERS BY COMMSCOPE DURING SETTLEMENT NEGOTIATIONS**

The MIL was **DENIED**. (Dkt. No. 494 at 68:23–69:21). The Court observed that conduct of both parties with response to offers, counteroffers, and negotiations relate and are relevant to the contractual obligation on the patentholder to offer licenses on a fair, reasonable, and non-discriminatory basis. The Court found that Federal Rule of Evidence 408 is applicable to non-FRAND encumbered patents. The Court cautioned counsel to keep distinct before the jury, the FRAND encumbered and non-FRAND encumbered patents being presented in this case, and counsel should avoid creating confusion in this regard.

CommScope's MIL 5	**COMMSCOPE'S CONTRIBUTIONS TO STANDARD-SETTING ORGANIZATIONS**

The MIL was **GRANTED**. (Dkt. No. 494 at 71:21–74:19). The Court precluded TQ Delta from labeling itself as a "giver" of technology and CommScope as a "taker" of technology. The Court, however, permits facts to be presented as to whether and/or how TQ Delta or CommScope have respectively contributed to the standard or participated in any standard setting body.

So ORDERED and SIGNED this 9th day of March, 2023.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC.,	(	CAUSE NO. 2:21-CV-310-JRG
	)	
Plaintiff,	(	
	)	
vs.	(	
	)	
COMMSCOPE HOLDING COMPANY,	(	
INC., et al.,	)	MARSHALL, TEXAS
	(	MARCH 24, 2023
Defendants.	)	8:00 A.M.

VOLUME 6

TRIAL ON THE MERITS

BEFORE THE HONORABLE RODNEY GILSTRAP
UNITED STATES CHIEF DISTRICT JUDGE

SHAWN McROBERTS, RMR, CRR
100 E. HOUSTON STREET
MARSHALL, TEXAS 75670
(903) 923-8546
shawn_mcroberts@txed.uscourts.gov

A P P E A R A N C E S

FOR THE PLAINTIFF: DAVIS FIRM, P.C.
213 N. FREDONIA ST., SUITE 230
LONGVIEW, TEXAS 75601
(903) 230-9090
BY: MR. RUDOLPH FINK
MR. CHRISTIAN HURT
MR. WILLIAM DAVIS

McANDREWS HELD & MALLOY, LTD
500 W. MADISON ST., 34TH FLOOR
CHICAGO, ILLINOIS 60661
(312) 775-8000
BY: MR. PETER McANDREWS
MS. ASHLEY RATYCZ
MR. RAJENDRA CHIPLUNKAR

FOR THE DEFENDANT: ALSTON & BIRD, LLP-NC
101 SOUTH TRYON STREET
SUITE 4000
CHARLOTTE, NC 28280
(704) 444-1025
BY: MR. ROSS BARTON
MR. MATTHEW STEVENS
MR. KIRK BRADLEY
MS. KARLEE WROBLEWSKI

ALSTON & BIRD, LLP - ATLANTA
ONE ATLANTIC CENTER
1201 WEST PEACHTREE STREET NW
#4900
ATLANTA, GEORGIA 30309-3424
(404) 881-7000
BY: MR. MICHAEL DEANE

THE DACUS FIRM, PC
821 ESE LOOP 323, SUITE 430
TYLER, TEXAS 75701
(903) 705-1117
BY: MR. DERON DACUS

OFFICIAL REPORTER: SHAWN M. McROBERTS, RMR, CRR
100 E. HOUSTON STREET
MARSHALL, TEXAS 75670
(903) 923-8546

THE COURT: Be seated, please.

Counsel, before the Court proceeds to conduct a formal charge conference regarding the final jury instructions and verdict form, let me inquire if there are exhibits that were used during yesterday's portion of the trial that were used for the first time and need to be read into the record as we have this week.

Are there additional exhibits that need to be read into the record?

MR. WILSON: There are, Your Honor.

THE COURT: Let's get that done, please.

MR. WILSON: Your Honor, Ty Wilson on behalf of Plaintiff TQ Delta, and at trial on March 22nd, 2023, TQ Delta admitted Exhibit 41 and Exhibit 118, just those two.

THE COURT: Any objection from Defendants?

MS. BEATON: No, Your Honor.

THE COURT: Do Defendants have a similar rendition to offer?

MS. BEATON: Yes, Your Honor.

THE COURT: Please proceed.

MS. BEATON: Erin Beaton on behalf of CommScope.

Yesterday, March 23rd, 2023, Defendants admitted Exhibit 59 and Exhibit 76.

THE COURT: All right. Any objections to that from the Plaintiff?

MR. WILSON: There's no objections, Your Honor.

THE COURT: Thank you, counsel.

All right. That having been completed, the Court will now conduct a formal charge conference regarding the final jury instructions and verdict form.

Yesterday at the conclusion of the evidence, after the Court took up and considered motions from both parties offered pursuant to Rule 50(a) of the Federal Rules of Civil Procedure, the Court thereafter met with counsel for the parties in chambers informally and at length and had a fulsome discussion regarding matters related to the final jury instructions and verdict form.

The Court was able to get important and constructive input from counsel and discuss issues related to these documents in a fulsome and constructive way.

The Court's taken into account the input received from the parties through that informal charge conference and has generated what it now believes to be the proper final jury instruction and verdict form to present to the jury this morning.

Before doing that, the Court will review these on the record with counsel and allow either party to lodge such objections to the same as they feel are necessary and appropriate.

Counsel, the way I have traditionally done this, for those not familiar with this Court's practice, is I've asked

that each side send a representative to the podium. And then we will begin with the final jury instructions, and I will go through them page by page. And at each page I'll ask if there are any objections from either party.

At that juncture if you believe something's been included which is improper or if you believe something necessary has been omitted, you may raise that objection on the record. Again, we'll do this on a page-by-page basis to ensure that nothing is missed or overlooked unintentionally.

When we've done that with the final jury instructions, we'll follow the same approach with regard to the verdict form.

So with that, whoever's going to speak for Plaintiff and whoever's going to speak for Defendants, please go to the podium and I'll just ask you to stay there as we go through the process to save us some time of going back and forth from counsel table.

Mr. Deane and Mr. Fink.

All right. Let's begin with the final jury instructions. Turning to the cover page or first page of those final jury instructions, is there objection here from either party?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: All right. Turning then to page 2, are there any objections here from either party?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Next is page 3. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Next is page 4. Are there objections here?

MR. FINK: None from the Plaintiff.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning then to page 5 of the final jury instructions, is there objection here from either party?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Turning then to page 6, is there any objection here?

MR. FINK: None from the Plaintiff.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Next is page 7. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Turning to page 8, are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.
THE COURT: Next is page 9. Are there objections?
MR. FINK: None from the Plaintiff.
MR. DEANE: None from the Defendant, Your Honor.
THE COURT: Next is page 10. Are there objections here?
MR. FINK: None from the Plaintiff, Your Honor.
MR. DEANE: None from the Defendant.
THE COURT: Turn to page 11, are there any objections from either party?
MR. FINK: None from the Plaintiff, Your Honor.
MR. DEANE: None from the Defendant.
THE COURT: Turning next to page 12, are there any objections?
MR. FINK: None from the Plaintiff, Your Honor.
MR. DEANE: None from the Defendant, Your Honor.
THE COURT: Next is page 13. Are there any objections?
MR. FINK: None from the Plaintiff, Your Honor.
MR. DEANE: None from the Defendant.
THE COURT: Next is page 14. Are there any objections?
MR. FINK: None from the Plaintiff, Your Honor.
MR. DEANE: None from the Defendant.
THE COURT: Next is page 15. Are there objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Turning then to page 16. Are there objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Next is page 17. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Next is page 18. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: There is an objection here for the Defendant, Your Honor.

THE COURT: State your objection.

MR. DEANE: In the paragraph dealing with the applicable priority date of the '686 Patent, the statement that TQ Delta contends that the applicable priority for the '686 Patent is no later than January 7th, 2000, we object to that instruction because we believe there is no evidence on the record of that date, and we also believe that there is no instruction that would resolve the dispute that's listed there.

THE COURT: All right. That objection is overruled.

Is there anything else from either party objecting to anything on page 18?

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Then we'll turn to page 19 of the final jury instructions. Is there any objection here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant.

THE COURT: Next is page 20. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning then to page 21, are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning to page 22, are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Next is page 23. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Next is page 24. Are there objections here?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: There is an objection here from the Defendant, Your Honor.

THE COURT: State your objection, please.

MR. DEANE: Your Honor, in the paragraph that starts with, The damages you award, there is a sentence that states, "You must not award TQ Delta more damages than are adequate to compensate for the infringement." The Defendant objects to the fact that that instruction does not limit the infringement to the patents-in-suit and only the patents-in-suit.

THE COURT: That objection's overruled. Anything further on page 24?

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Let's turn next to page 25. Are there objections here?

MR. FINK: Yes, Your Honor. From the Plaintiff, for the first paragraph and the second sentence that begins, This approach relies upon estimated costs, Plaintiff objects to the language in that sentence and the following sentence and would propose that the language be changed in the second sentence to, This approach relies upon estimated costs, if any, that the making, using, or selling of the accused products save.

And the following sentence, Plaintiff would change the language to, In considering the amount of reasonable royalty damages under the cost savings model, you should focus on

whether CommScope's making, using, or selling of the patented technology avoided taking a different, more costly course of action. And the rest of the sentence would stay the same.

So essentially that's for the second sentence striking the 'allowed it to' language and changing 'avoid' to 'avoided'.

THE COURT: All right.

MR. FINK: Thank you.

THE COURT: Is that all of Plaintiff's objections, Mr. Fink?

MR. FINK: Yes, Your Honor.

THE COURT: Okay. That objection is overruled.

Anything further from either party on page 25?

MR. DEANE: Yes, Your Honor. Defendant also objects to the same paragraph that the Plaintiff objected to.

THE COURT: All right. That objection is overruled.

There is on this page, counsel, an unintended typo where the Court has put Defendant singular. It needs to be Defendants. See if I can find it.

MR. DEANE: Your Honor, I believe it's the second line.

THE COURT: No. I think that's where it was, Mr. Deane. I think I've already corrected it before I got out here. The word Defendants on the second line should be plural as there are multiple Defendants collectively referred to as

CommScope. But that's where it was. And as I stated, in an earlier version I remember it being there, but I see that it's already been corrected. So that will address that concern.

Anything further from either party on page 25?

MR. FINK: So, Your Honor, just -- just to be clear, I believe what CommScope is saying, the version that the parties have, that it's the defendant singular on that second line?

THE COURT: Right.

MR. FINK: Okay.

THE COURT: This was caught after the email to you and before I got out here. So that's why I've got it corrected and you don't.

MR. FINK: Understood, Your Honor.

THE COURT: But it will be Defendants plural.

MR. FINK: No objection from Plaintiff.

THE COURT: All right. Let's turn to page 26 of the final jury instructions. Are there any objections here from either Plaintiff or Defendants?

MR. FINK: No objection from Plaintiff, Your Honor.

MR. DEANE: No objection from Defendant, Your Honor.

THE COURT: All right. Turning to page 27, are there any objections here?

MR. FINK: No objection from Plaintiff, Your Honor.

MR. DEANE: No objection from Defendant, Your Honor.

THE COURT: All right. And, counsel, you'll note pages 26 and 267 contain all 15 of the *Georgia Pacific* factors. I gather neither party objects to the Court charging this jury on all 15 factors. Is that correct?

MR. FINK: Plaintiff does not, Your Honor.

MR. DEANE: No objection from Defendant, Your Honor.

THE COURT: Is there any objection from either party on page 27?

MR. FINK: No objection from Plaintiff, Your Honor.

MR. DEANE: No objection from Defendant.

THE COURT: Then we'll turn to page 28 of the final jury instructions. Are there any objections here?

MR. FINK: No objection from Plaintiff, Your Honor.

MR. DEANE: No objection from Defendant.

THE COURT: Next is page 29. Are there any objections here?

MR. FINK: No objection from Plaintiff, Your Honor.

MR. DEANE: No objection from Defendant, Your Honor.

THE COURT: Next then is page 30. Are there any objections here?

MR. FINK: No objection from Plaintiff, Your Honor.

MR. DEANE: There is an objection from the Defendant, Your Honor.

THE COURT: State your objection, please.

MR. DEANE: Your Honor, in the last full paragraph

where it discusses the patent expiration dates, it lists two patents which are expired. The Defendant objects to the fact that a third patent is not listed, which is the '686 Patent, which we believe expired on October 1st, 2022.

THE COURT: Mr. Fink, does the Plaintiff have any reason why that third patent, if in fact it has expired, should not be listed there with the other two?

MR. FINK: Plaintiff overall has no objection to listing an expiration date for the '686 Patent. I believe the issue here was that the -- at least from the Plaintiff's perspective, it's seeking damages from June 30, 2022. So at that, the patent has yet to expire.

THE COURT: All right. In other words, the period of time through which the evidence has been presented to the jury was a period of time when this particular patent was still in force.

MR. FINK: That's Plaintiff's understanding, Your Honor.

THE COURT: All right. Then I'll overrule the Defendants' objection.

All right. Anything further on page 30 from either party?

MR. FINK: None from Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Let's turn next to page 31. Are there

objections here from either party?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Next is page 32. Are there any objections here?

MR. FINK: Briefly from the Plaintiff, Your Honor. For the, I guess, paragraph that begins, If you find that TQ Delta has breached its contractual obligation, TQ Delta objects to the instruction of compensatory damages here as it does not believe that there has been evidence.

THE COURT: All right. That's overruled. Anything further on page 32?

MR. FINK: None from Plaintiff, Your Honor.

MR. DEANE: No objection from Defendant, Your Honor.

THE COURT: All right. Let's turn to page 33. Are there any objections here from either party?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: All right. Page 34, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: All right. Page 35, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: All right. And does page 35 represent the final page in the version you gentlemen have?

MR. FINK: Your Honor, I have page 36 at least.

THE COURT: All right. I want to make sure that we are looking at the same thing.

Are there any objections from either party on the final page being page 36?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: All right. Thank you, counsel.

Let's proceed to consider the verdict form in the same manner. Let's begin with that document, and we'll turn first to the cover sheet or page 1. Is there any objection here from either party?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning to page 2 where various definitions are set forward, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Page 3 where various instructions to the jury are included, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning, then, to page 4 where Question 1 is found, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning to page 5 where Question 2 is found, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning, then, to page 6 where Question 3 is found, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Turning to page 7 where Questions 4A and 4B are found, are there any objections?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: Your Honor, the Defendant has an objection.

THE COURT: State your objection.

MR. DEANE: For Question No. 4A, Defendant objects to the fact that the request to the jury is not split out between induced infringement and direct infringement.

THE COURT: All right. That objection's overruled.

Anything further on page 7?

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Then we'll turn to page 8 of the verdict

form where Questions 5 and 6 are found. Are there objections here from either party?

MR. FINK: Briefly, Your Honor. Plaintiff objects that the inclusion of a blank for compensation of damages on breach of contract, which it does not believe have been proven in any way.

THE COURT: All right. That objection's overruled.

Anything further?

MR. FINK: None from the Plaintiff, Your Honor.

MR. DEANE: None from the Defendant, Your Honor.

THE COURT: Thank you.

We'll turn to page 9, which is the final page of verdict form. Are there any objections here from either party?

MR. FINK: Oh, sorry, Your Honor. May I briefly -- we had another objection on page 8. I'm sorry.

THE COURT: All right. Just for completeness, let's turn to page 8.

What was your additional objection, Mr. Fink?

MR. FINK: For Question 5, Your Honor, Plaintiff also objects that the statement of the contractual duty should be a contractual duty to grant licenses regarding its standard essential patents to CommScope on a worldwide reasonable and non-discriminatory basis, not a -- yeah. CommScope--sorry--TQ Delta does not believe that the obligation was specifically United States; that it was for a worldwide basis only.

THE COURT: All right. And the question does not, as you can see, identify either on a U.S. or a worldwide basis. It's silent on that.

MR. FINK: Yes, Your Honor.

THE COURT: Okay. All right. Your objection's overruled.

Anything else from either party on any of the provisions in the verdict form?

MR. FINK: None from Plaintiff, Your Honor.

MR. DEANE: None from Defendant, Your Honor.

THE COURT: All right. Thank you, counsel.

That will complete the formal charge conference. As I indicated to you yesterday, I'll now produce eight printed copies of the final jury instructions and one clean copy of the verdict form, which I intend to send back to the jury after my instructions are complete and closing arguments have been heard.

Now that we are at this point, Mr. Davis, can you confirm that you will be presenting the entirety of Plaintiff's closing arguments?

MR. DAVIS: Yes, Your Honor.

THE COURT: All right. Mr. Barton or Mr. Dacus, either one, who will be presenting arguments for Defendants?

MR. DACUS: I will be, Your Honor.

THE COURT: All right. You're not going to split

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC, *Plaintiff*, v. COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS US HOLDINGS, INC., ARRIS SOLUTIONS, INC., and ARRIS ENTERPRISES, LLC, *Defendants*.	§ § § § § § § § § § § § §	CIVIL ACTION NO. 2:21-CV-00310-JRG [redacted]

MEMORANDUM OPINION AND ORDER

Before the Court is Plaintiff TQ Delta, LLC's ("TQ Delta") Motions for a New Trial on Damages and the Validity of U.S. Patent No. 8,462,835, and Conditional Motion for a New Trial on Additional Damages for Infringement of U.S. Patent Nos. 8,462,835, 8,090,008, and 7,570,686 (the "Motion"). (Dkt. No. 538.) Having considered the Motion and the related briefing, and for the reasons that follow, the Court finds that the Motion should be and hereby is **DENIED**.[1]

I. BACKGROUND

On August 13, 2021, TQ Delta filed the above-captioned case against CommScope Holding Company, Inc., CommScope Inc., Arris International Limited, Arris Global Ltd., Arris US Holdings, Inc., Arris Solutions, Inc., and Arris Enterprises, LLC (collectively, "CommScope"), asserting infringement of thirteen patents. (*See* Dkt. No. 1.) CommScope answered the Complaint on October 22, 2021, asserting the defenses of invalidity and noninfringement. (*See* Dkt. No. 17.)

[1] The Court notes that TQ Delta failed to follow Local Rule CV-7(a) by including multiple motions in a single document. Since the Court denies each matter contained within Dkt. No. 538, it rules on the Motion as a whole. However, had the Court agreed with any of the individual requests for relief contained therein, TQ Delta would have been ordered to refile the Motion as separate motions.

By the time of trial, TQ Delta had narrowed its case, and trial commenced with TQ Delta asserting infringement of claim 36 of U.S. Patent No. 7,570,686 (the "'686 Patent"), claim 17 of U.S. Patent No. 7,453,881 (the "'881 Patent"), claim 5 of U.S. Patent No. 8,276,048 (the "'048 Patent"), claim 14 of U.S. Patent No. 8,090,008 (the "'008 Patent"), claim 10 of U.S. Patent No. 8,462,835 (the "'835 Patent"), claim 18 of U.S. Patent No. 8,468,411 (the "'411 Patent"), and claim 10 of U.S. Patent No. 9,154,354 (the "'354 Patent") (collectively, the "Asserted Claims"). (Dkt. No. 495 at 1.) CommScope similarly narrowed its invalidity theories to target only claim 36 of the '686 Patent, claim 5 of the '048 Patent, claim 14 of the '008 Patent, and claim 10 of the '835 Patent. (Dkt. No. 497.) CommScope asserted that claim 36 of the '686 Patent and claim 5 of the '048 Patent were invalid as obvious, and that claim 14 of the '008 Patent and claim 10 of the '835 Patent were invalid as either anticipated or if not, obvious. (*Id.* at 2.)

On March 17, 2023, a jury trial commenced in this case. After the close of evidence on March 23, 2023, the Court took up matters from both sides under Federal Rule of Civil Procedure 50(a), where TQ Delta moved that claim 36 of the '686 Patent, claim 5 of the '048 Patent, claim 14 of the '008 Patent, and claim 10 of the '835 Patent were not proven to be invalid during trial. (*See* Dkt. No. 533 at 228:5-229:14, 229:15-230:24, 232:15-22.) TQ Delta's Rule 50(a) Motions as to the '686, '048, '008, and '835 Patents were denied.

On the morning of March 24, 2023, the Court held a formal charge conference where it took up challenges to the jury instructions. (*See* Dkt. No. 534.) In relevant part, the jury instructions included the following:

> TQ Delta, the Plaintiff, has proposed a cost-savings model of calculating reasonable royalty damages that values the Accused Products that CommScope, the Defendant, provides to its customers. This approach relies upon estimated costs, if any, that CommScope saved from making, using, or selling the Accused Products. In considering the amount of reasonable royalty damages under the cost-savings model, you should focus on whether CommScope's make, use, or sale of the patented technology allowed it to avoid taking a

> different, more costly course of action, and if so, how much CommScope saved by using the Accused Products instead of taking the more costly course of action.

(Dkt. No. 538-1 at 25.) When asked if there were any objections to this provision of the jury instructions, TQ Delta objected as follows:

> **THE COURT**: Let's turn next to page 25. Are there objections here?
>
> **MR. FINK**: Yes, Your Honor. From the Plaintiff, for the first paragraph and the second sentence that begins, This approach relies upon the estimated costs, Plaintiff objects to the language in the sentence and the following sentence and would propose that the language be changed in the second sentence to, This approach relies upon estimated costs, if any, that the making, using, or selling of the accused products save.
>
> And the following sentence, Plaintiff would change the language to, In considering the amount of reasonable royalty damages under the cost savings model, you should focus on whether CommScope's making, using, or selling of the patented technology avoided taking a different, more costly course of action. And the rest of the sentence would stay the same. So essentially that's for the second sentence striking the 'allowed it to' language and changing 'avoid' to 'avoided'.

(Dkt. No. 534 at 10:14–11:6.) TQ Delta's objection was overruled. (*Id.* at 11:12.)

That afternoon, the Jury returned its verdict. (*See* Dkt. No. 508.) In pertinent part, the Jury found that CommScope infringed claim 17 of the '881 Patent, claim 36 of the '686 Patent, claim 5 of the '048 Patent, claim 10 of the '835 Patent, claim 18 of the '411 Patent, and claim 10 of the '354 Patent.[2] (*Id.* at 4.) The Jury also found that CommScope's infringement was willful. (*Id.* at 6.) However, the Jury also found the claim 36 of the '686 Patent and claim 10 of the '835 Patent were invalid. (*Id.* at 5.) The Jury assessed damages against CommScope in the amount of $11,125,000. (*Id.* at 7.)

Accordingly, on May 3, 3023, the Court entered final judgment on the verdict, ordering and entering judgment that CommScope infringed claim 17 of the '881 Patent, claim 36 of the '686 Patent, claim 5 of the '048 Patent, claim 10 of the '835 Patent, claim 18 of the '411 Patent,

[2] The Jury further found that claim 14 of the '008 Patent was not infringed and not invalid. (Dkt. No. 508 at 4–5.) The Court rendered final judgment on the verdict. (*See* Dkt. No. 513 at 2.)

and claim 10 of the '354 Patent. (Dkt. No. 513 at 2.) It further ordered that claim 10 of the ‘835 Patent and claim 36 of the ’686 Patent were invalid. (*Id.*) The Court observed in footnote 1 of its judgment that:

> Though the verdict indicates the Jury found these claims to be infringed, their related finding of invalidity is a defense to such infringement and the Court does not consider the infringement of these claims to be operable or compensable. The Court clearly instructed the Jury that invalidity is a defense to infringement, and the Court finds their verdict is consistent with the Court’s instructions.

(*Id.* at 1 n.1.) The Court awarded damages to TQ Delta in the amount of $11,125,000. (*Id.* at 2.)

TQ Delta now seeks a new trial on damages due to alleged error relating to the jury instructions and admission of evidence. (Dkt. No. 538 at 1.) It also seeks a new trial on the validity of the ’835 Patent. (*Id.*) Further, TQ Delta conditionally moves for a new trial on additional damages to the extent that the Court grants one or more of TQ Delta’s motions for JMOL of infringement of the ’008 Patent (Dkt. No. 539), no invalidity of the ’686 Patent (Dkt. No. 538), or no invalidity of the ’835 patent (*id.*), or TQ Delta’s motion for a new trial on validity of the ’835 Patent. (Dkt. No. 538 at 15.)

II. LEGAL STANDARD

“[C]ourts do not grant new trials unless it is reasonably clear that prejudicial error has crept into the record or that substantial justice has not been done, and the burden of showing harmful error rests on the party seeking the new trial.” *Metaswitch Networks Ltd. v. Genband US LLC*, 2017 U.S. Dist. LEXIS 137926, at *8 (E.D. Tex. Aug. 28, 2017). “A new trial may be granted, for example, if the district court finds the verdict is against the weight of the evidence, the damages awarded are excessive, the trial was unfair, or prejudicial error was committed in its course.” *Smith v. Transworld Drilling Co.*, 773 F.2d 610, 612–13 (5th Cir. 1985); *see also Laxton v. Gap Inc.*, 333 F.3d 572, 586 (5th Cir. 2003). Furthermore, “[u]nless justice requires otherwise, no error in admitting or excluding evidence—or any other error by the court or a party—is ground for granting

a new trial. . . .[T]he court must disregard all errors and defects that do not affect any party's substantial rights." Fed. R. Civ. P. 61.

III. DISCUSSION

TQ Delta moves for a new trial on damages and a new trial on the validity of the '835 Patent. TQ Delta first alleges that the Court committed prejudicial error in its jury instruction on TQ Delta's damages model, warranting a new trial on damages. (Dkt. No. 538 at 6.) Next, TQ Delta argues that the Court erred in permitting CommScope's expert, Dr. Becker, to testify that TQ Delta's royalty should be based on the price of only the DSL chip, independently necessitating a new trial on damages. (*Id.* at 10.) Third, TQ Delta moves that there should be a new trial on the validity of the '835 Patent due to the Court's alleged error in striking paragraphs 69–72 of TQ Delta expert Dr. Madisetti's rebuttal report. (*Id.* at 13.) Lastly, TQ Delta conditionally moves for a new trial on additional damages to the extent that its various other motions are granted. (*Id.* at 15.) CommScope opposes all aspects of the Motion. (*See generally* Dkt. No. 548.) The Court now turns to the substance of the Motion.

A. Motion for New Trial on Damages

i. Jury Instruction on Damages

A party seeking a new trial based on erroneous jury instructions must establish that (1) it made a proper and timely objection to the jury instructions, (2) those instructions were legally erroneous, (3) the errors had prejudicial effect, and (4) it requested alternative instructions that would have remedied the error. *Advanced Display Sys. v. Kent State Univ.*, 212 F.3d 1272, 1281 (Fed. Cir. 2000). "Prejudicial error exists when it 'appears to the court [that the error is] inconsistent with substantial justice.'" *Id.* at 1283 (quoting Fed. R. Civ. P. 61). However, if a party failed to properly preserve its objection, Rule 51(d)(2) provides that a "court may consider a plain

error in the instructions that has not been preserved as required by Rule 51(d)(1) if the error affects substantial rights." In order to prevail under the plain error standard, the moving party must show: "(1) that an error occurred; (2) that the error was plain, which means clear or obvious; (3) the plain error must affect substantial rights; and (4) not correcting the error would 'seriously affect the fairness, integrity, or public reputation of judicial proceedings." *Russell v. Plano Bank & Trust*, 130 F.3d 715, 719 (5th Cir. 1997) (internal citations omitted).

At trial, TQ Delta put forth damages evidence based on a cost-savings damages model used by TQ Delta's damages expert, Dr. Putnam. (Dkt. No. 538 at 1.) TQ Delta asserted infringement of both standard essential patents ("SEPs") and non-SEPs. (*Id.*) Dr. Putnam testified that he used a cost-savings model to calculate TQ Delta's reasonable royalty damages for infringement of the SEPs that relied on the cost savings that AT&T, CommScope's customer, realized by using standardized DSL technology in the accused products instead of Fiber to the Premises ("FTTP") technology. (*Id.* at 1–2, citing Dkt. No. 532 at 14:1–22:15; 102:20–105:16.) He relied on the same model for non-SEPs based on cost savings realized by CommScope's chipmaker. (*Id.* at 2, citing Dkt. No. 532 at 40:2–20; 48:19–23.) TQ Delta now argues that it is entitled to a new trial on damages because the Court committed prejudicial error by instructing the Jury that TQ Delta's damages model relied on CommScope's cost-savings, rather than AT&T's or the chipmaker's. (Dkt. No. 538 at 6.)

a. Propriety of Objection to Cost-Saving Instruction

TQ Delta asserts that it preserved error in compliance with Fed. R. Civ. P. 51(c)(1) by timely objecting and asking the Court to modify the erroneous instruction by genericizing who benefits from the cost savings. (*See id.* at 3, citing Dkt. No. 534 at 10:14–11:11.) It urges that its objection and proposed modifications to portions of the instruction clearly indicated the basis for

the objection. (Dkt. No. 555 at 1.) Further, it notes that this issue was "raised repeatedly with the Court right up to the charge conference in motions (*Daubert* and Rule 50(a)), testimony, and even an email CommScope sent to the Court the night before the conference proposing an instruction genericizing the beneficiary of cost savings." (*Id.*, emphasis in original.)[3] TQ Delta concludes that given this context, its objection stated distinctly the matter objected to and the grounds for the objection. (*Id.*, citing Fed. R. Civ. P. 51(c).) Further, TQ Delta notes that CommScope objected to the same instruction, and that CommScope had "previously proposed an instruction that genericized who realized the cost savings benefits." (*Id.* at 7, citing Dkt. No. 534 at 11:13-15; Dkt. No. 538-2 at 5.)

CommScope, on the other hand, contends that TQ Delta failed to properly object to the cost-savings instruction (the "CSI") such that review of the jury instruction is limited by the exacting "plain error" standard. (Dkt. No. 548 at 2, 4, citing *Russell*, 130 F.3d at 721.) According to the Fifth Circuit, Fed. R. Civ. P. 51(c)(1) is satisfied when a party "specifically object[s] to an instruction prior to the jury's deliberation and stat[es] the reason for its objection." *Advanced Display*, 212 F.3d at 1282 (applying 5th Circuit law). CommScope urges that TQ Delta's objection did not constitute a distinct statement of the grounds for its objection, but instead simply proposed an alternative instruction. (*Id.* at 3, citing *Russell*, 130 F.3d at 719 ("A party does not satisfy [Rule 51(c)] merely by submitting to the court a proposed instruction that differs from the instruction ultimately given to the jury.").)

CommScope asserts that TQ Delta's contention that its proposed modifications "clearly indicated the basis for the objection" and its citation to evidence outside the objection (Dkt. No.

[3] For support, TQ Delta cites the following: Dkt. No. 531 at 14:1-22:15, 102:20-105:16; Dkt. No. 346 at 3; 3/1/23 Tr. at 72:1-11, 96:7-17, 97:22-99:25; Dkt. No. 496 at 5; 3/23/23 Tr. at 74:9-23, 98:5-99:20, 243:17-245:9, 249:6-11; Dkt. No. 542-2.

555 at 1) demonstrates the insufficiency of its objection—TQ Delta was required to *state* the reason for its objection. (*See* Dkt. No. 562 at 2–3.) Furthermore, it argues that a party must make a formal objection during the charge conference even if "it has already made its position clear to the district court." (*Id.*, citing *Jimenez v. Wood County*, 660 F.3d 841, 846 n.7 (5th Cir. 2011).) Since TQ Delta only proposed alterations to the CSI, CommScope insists that review is limited by the plain error standard, which it asserts TQ Delta has not proved is met. (Dkt. No. 548 at 4–5.)

The Court is of the opinion that TQ Delta's objection to the instruction was not sufficiently specific because it did not set forth a distinct statement of the grounds for the objection. TQ Delta's objection simply proposed an alternative instruction. It did not state any reason or rationale for its objection. It did not urge the Court in its formal objection, as it does now, that its damages model was premised on cost savings to non-parties rather than to CommScope. The "context" in which the objection was made does not control the analysis—the jury instructions were twenty-five pages long, and there were a multitude of disputed issues throughout the case. It is not the Court's responsibility to know or recall the "context" for any objection. This is why an objection must specifically set forth the grounds for such objection. The objection here failed to do so. However, because the Court is of the opinion that the Motion fails based on the lower standard premised on legal error and prejudice, it analyzes TQ Delta's argument as set forth below and notes that the failure to satisfy the lower standard necessarily results in a failure to satisfy the higher plain error standard.[4]

b. Legal Error

TQ Delta argues not only that the CSI was inconsistent with Dr. Putnam's testimony, but that it was legally erroneous. (Dkt. No. 538 at 6.) TQ Delta notes that it is "well accepted" that a

[4] TQ Delta cursorily acknowledged the possibility of plain error review in its Motion and recited the elements in a footnote, asserting that the CSI constitutes plain error. (Dkt. No. 538 at 10 n.4; Dkt. No. 555 at 2.)

patentee may base reasonable royalty damages on a cost-savings model. (*Id.* at 7, citing *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075, 1081–82 (Fed. Cir. 1983).) Further, TQ Delta claims (without citing authority) that "there is no requirement that a cost-savings model be based on the cost-savings of the defendant and to the exclusion of the defendant's customer for the infringing product." (*Id.*)

To support its argument, TQ Delta contends that the lack of a requirement that the model be based on the defendant's savings is logical because in many cases, it is the accused infringer's customer that realizes the benefit of use of patented technology. (*Id.* at 7–8.) TQ Delta notes that it is limited to one recovery by the law, unable to recover damages for successive infringers of the same product in the supply chain. (*Id.* at 8, citing *Cal. Inst. of Tech. v. Broadcom Ltd.*, 25 F.4th 976, 994 (Fed. Cir. 2022).) Since it chose to sue the manufacturer, TQ Delta argues, it can base its damages on the cost-savings of the end-user customers and chip supplier to ensure its recovery adequately compensates it for the value of its patents. (*Id.* at 8, citing *Stickle v. Heublein Inc.*, 716 F.2d 1550, 1562 (Fed. Cir. 1983) ("the quantum of [the patent owner's] recovery for an infringing [product] does not depend on whether [the user] or [the maker/seller] is the defendant.").) Lastly, TQ Delta boldly claims that "the Court has already found that [TQ Delta's] cost savings theory is sufficiently reliable and rooted in law" because it denied CommScope's motion to exclude Dr. Putnam's damages testimony as "inconsistent with legal precedent." (*Id.* at 9, citing Dkt. No. 496 at 5.)

CommScope responds that the Court's instruction was not legally erroneous because the Court, consistent with long-standing legal precedent, instructed the Jury that the cost-savings model focuses on savings to the defendant. (*Id.* at 5–6.) Indeed, CommScope contends that TQ Delta's assertion that there is no requirement that cost-savings must be based on savings to the

defendant "flies in the face of Federal Circuit precedent." (*Id.* at 6.) It contends that such precedent makes clear that a cost-savings model is based on the savings to the defendant acting as a willing licensee in a hypothetical negotiation.[5] (*Id.*) Further, CommScope points out that TQ Delta failed to cite a single case establishing that the cost savings to a third party to the hypothetical negotiation may form the basis of a reasonable royalty calculation,[6] or that the Court was required to instruct the Jury about the factual nuances of TQ Delta's cost-savings approach. (*Id.* at 7.)

CommScope asserts that basing the cost-savings model on the savings to the defendant simply makes sense, in addition to being consistent with legal precedent. (*Id.* at 6.) It points to 35 U.S.C. § 284, which requires that a damages award be no less than a reasonable royalty for use made of the invention by the *infringer*. (*Id.*) CommScope additionally contends that TQ Delta's argument regarding the law of exhaustion lacks merit; TQ Delta chose to sue CommScope, not AT&T (the customer) or Broadcom (the chip supplier). (*Id.*) CommScope argues that *Stickle* does not say that damages may be based on cost savings to an accused infringer's downstream customers. (*Id.* at 7.) Instead, in *Stickle*, the cost-savings approach was based on the savings to an accused user, rather than a third-party downstream user. (*Id.* at 7, citing 716 F.2d at 1562.) Lastly, CommScope argues that the Court's denial-in-part of CommScope's motion to exclude Dr. Putnam's expert testimony was not a previous ruling on whether Dr. Putnam's cost savings approach was "rooted in law." (*Id.* at 6 n.3.)

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[5] CommScope cites the following cases in support of its proposition that the cost-savings approach properly focuses on the cost savings to the defendant and willing licensee: *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075, 1080–81 (Fed. Cir. 1983); *Prism Techs. LLC v. Sprint Spectrum L.P.*, 849 F.3d 1360, 1375–76 (Fed. Cir. 2017); *Powell v. Home Depot U.S.A., Inc.*, 663 F.3d 1221, 1240–41 (Fed. Cir. 2011); *Aqua Shield v. Inter Pool Cover Team*, 774 F.3d 766, 771–72 (Fed. Cir. 2014); *Mobile Equity Corp. v. Walmart Inc.*, No. 2:21-cv-00126-JRG-RSP, 2022 U.S. Dist. LEXIS 175050, at *8–9 (E.D. Tex., Sept. 27, 2022).

[6] CommScope notes that *Hanson*, the "sole case TQ Delta cites in support" of its model, focused on the cost savings to the defendant acting as a willing licensee. (*Id.* at 6 n.4, citing *Hanson*, 718 F.2d at 1079.)

As an initial matter, the Court did not find that Dr. Putnam's damages model was "rooted in law" as TQ Delta contends; as CommScope points out, the Court's role as gatekeeper is to ensure that a proposed expert's testimony is sufficiently reliable and relevant to the issues at hand to be submitted to the Jury. *See* Fed. R. Evid. 702; *Daubert v. Merrell Dow Pharms.*, 509 U.S. 579 (1993). The Court's denial-in-part of CommScope's motion to exclude Dr. Putnam's testimony did not predetermine the jury instructions in this case. Importantly, none of the express bases for CommScope's *Daubert* challenge were that the cost savings model was not based on a third party's savings.[7] The Court's order in its Order on Pretrial Motions (Dkt. No. 496) was that Dr. Putnam's opinions were not so flawed as to require exclusion. Such a ruling was a far cry from an affirmative ruling that TQ Delta's damages theory was "rooted in law" as related to a non-party user's savings being the basis for a cost-saving approach.

Further, the Court is unpersuaded that the jury instruction as given constituted legal error. While CommScope has pointed to no precedent affirmatively holding that the cost-savings approach is limited to the cost savings of the defendant, TQ Delta has not pointed to any case in which the cost-savings approach was premised upon savings to a non-party end user (such as AT&T here). Rather, the cases cited by CommScope demonstrate that cost-savings approach properly focuses on the cost savings to the defendant and willing licensee. (*See* footnote 6, *supra*.) In contrast, TQ Delta first cites the *Hanson* case, stating that it did not limit cost savings to a defendant (Dkt. No. 555 at 2)—yet, that case itself focuses on the cost savings to the defendant acting as willing licensee. *Hanson*, 718 F.2d at 1079. TQ Delta's reliance on *Stickle* fares no better.

[7] The motion to exclude contained five grounds for exclusion: (1) Dr. Putnam's methodology failed to limit damages to the incremental value of the asserted patents (Dkt. No. 346 at 5); (2) Dr. Putnam improperly rejected the SSPPU Rule of the Federal Circuit (*id.* at 8); (3) Dr. Putnam improperly relied on the Nash Bargaining Theory (*id.* at 10); (4) Dr. Putnam used an incorrect date for the hypothetical negotiation (*id.* at 11); and (5) Dr. Putnam's methodology produces unreliable damages numbers (*id.*). (*See also* Dkt. No. 496 at 5.)

As CommScope correctly points out, the Federal Circuit in *Stickle* rejected a use-based royalty based off the user's (and accused infringer's) use of the accused products because there was no evidence in the record that a willing licensor could have reasonably expected to secure a use royalty from either the maker or the user. *See Stickle*, 716 F.2d at 1562. The Court does not find that *Stickle* stands for the general proposition that the cost-savings approach may be based on the cost savings to a third-party downstream user like AT&T here. This Court is persuaded that the CSI was grounded in Federal Circuit precedent and legally accurate. *See, e.g., Hanson*, 718 F.2d at 1081 (referencing the determination of the *defendant's* cost savings based on use).

In sum, the Court instructed the Jury that TQ Delta utilized a cost savings approach; it instructed the Jury that such an approach relies upon on cost savings to CommScope (the defendant), consistent with legal precedent, and that the Jury should focus on such savings. Nothing in the charge instructed the Jury to disregard the evidence it heard from Dr. Putnam regarding AT&T or Broadcom's cost savings. As discussed below, even if the CSI was legally erroneous and (it was not), the error was not prejudicial and a new trial is not warranted.

c. Prejudice

TQ Delta asserts that the CSI necessarily confused and misled the Jury, effectively telling the Jury to disregard Dr. Putnam's damages model by erroneously describing it as relying on CommScope's cost savings, which Dr. Putnam presented no evidence on. (Dkt. No. 538 at 8.) TQ Delta claims that the instruction "gutted [TQ Delta's] damages case and unfairly cast doubt on the sufficiency of [its] damages evidence and the credibility of Dr. Putnam and his model." (*Id.*) According to TQ Delta, the Jury could only have concluded that Dr. Putnam's damages model had

no supporting evidence and was forced instead to rely on CommScope's damages model.[8] (*Id.* at 8–9.) Accordingly, argues TQ Delta, there should be a new trial on damages where the Jury is properly instructed on TQ Delta's damages model. (*Id.* at 9.)

In contrast, CommScope asserts that the CSI had no prejudicial effect on TQ Delta. (Dkt. No. 548 at 7.) It contests TQ Delta's assertion that the CSI told the Jury to disregard Dr. Putnam's damages model; instead, the Court accurately recited the applicable law and expressly told the jury that it "may use either [party's] method." (*Id.*, citing Dkt. No. 532 at 59:14–60:11.) Further, CommScope asserts that TQ Delta's ability to present its arguments was not hampered by the instruction. (*Id.* at 8, citing *Delaronde v. Legend Classic Homes, Ltd*., 716 Fed. Appx. 322, 327 (5th Cir. 2018) ("When a jury is properly instructed regarding the controlling law and counsel is able to present the jury with inferences it was permitted to make from the evidence, this court cannot conclude a party was seriously impaired in presenting its claim.").) Lastly, CommScope points out that the Jury awarded TQ Delta over $11 million in damages, a number between TQ Delta's and CommScope's proposed damages numbers. (*Id.*) The Jury heard evidence regarding two methods and the controlling law, and it was free to make its own findings based on the credibility of the methodologies. (*Id.*)

TQ Delta responds that the Court misstated TQ Delta's cost-savings model, the law, and the jury's required focus. (Dkt. No. 555 at 3.) Further, it contends that because TQ Delta had already closed its evidentiary presentation proving cost savings to AT&T and Broadcom, it was prevented from presenting arguments addressing cost savings to CommScope as the CSI required. (*Id.*) Since the Jury was required to faithfully follow the instructions, TQ Delta urges that it could

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[8] Dr. Becker's highest potential damages number, as presented to the Jury, was $5.7 million. (*See* Dkt. No. 534 at 114:23–25.) Given that the Jury awarded $11,125,000.00, it is hard to see how the Jury could have been forced to rely on CommScope's damages model.

not have considered any cost savings other than CommScope's. (*Id.*) Without any compelling logic, it urges that the resulting damages award between TQ Delta's and CommScope's proposed numbers does not disprove this. (*See id.*) CommScope answers that the Court never told the Jury that it could not base damages on the cost-savings to AT&T or that TQ Delta's damages model could not be considered. (Dkt. No. 562 at 3.) CommScope asserts that the Court did not misstate TQ Delta's damages model (a cost savings approach), the law, or the jury's focus. (*Id.*)

Even taking as true TQ Delta's arguments that the CSI was legally erroneous (and as discussed *supra*, the Court found no legal error), the Court is unpersuaded that the jury instruction as given materially prejudiced TQ Delta. The instruction did not preclude the Jury from considering Dr. Putnam's testimony regarding cost-savings to AT&T and Broadcom; indeed, nothing in the jury instructions barred consideration of those savings as attributable to CommScope. TQ Delta urges that the only damages model the Jury could have considered while faithfully adhering to the instructions was CommScope's model. However, the resultant damages number awarded directly contradicts this argument—the Jury arrived at a total award between both TQ Delta and CommScope's proposals. TQ Delta proposed $89 million as a reasonable royalty. (Dkt. No. 534 at 85:20–23.) CommScope proposed $5.7 million, should the jury found infringement of all seven patents. (*Id.* at 114:23–25.) After ultimately finding that the infringement of four out of seven patents was compensable,[9] the Jury arrived at a total award of $11,125,000. (Dkt. No. 508 at 7.) Clearly, the Jury did not take only CommScope's damages model into account, nor was it instructed to. Prejudicial error exists where it appears to the Court that the error is inconsistent with substantial justice. *Advanced Display*, 212 F.3d at 1283 (quoting Fed. R. Civ. P.

[9] Although the Jury found that six out of the seven Asserted Patents were infringed, it found that two of the infringed patents were invalid. (*See* Dkt. No. 508 at 4–5.) The Jury was instructed that "[i]nvalidity is a defense to infringement" (Dkt. No. 538-1 at 9), and therefore did not take those two patents into account (nor the patent that was not found to be infringed) in the calculation of damages.

61). As the complained of prejudice is contradicted by the Jury's own verdict, the Court finds no prejudice that justifies overturning that verdict—certainly not an error inconsistent with "substantial justice."

d. Alternative Instruction

TQ Delta asserts that the Court committed error by failing to modify the CSI, noting that CommScope itself agreed with TQ Delta's proposed modifications. (Dkt. No. 555 at 3–4, citing Dkt. No. 542-2; Dkt. No. 534 at 11:12.) It again argues that its proposed instruction was a correct statement of the law and was not covered in the charge as a whole because "nowhere else was the jury told that damages could be based on cost savings other than CommScope's[.]" TQ Delta again argues that the proposed instruction was necessary to avoid impairing TQ Delta's ability to prove its damages case under the legal standards dictated by the Court. (*Id.*)

CommScope contends that the Court did not err by declining to "genericize" who benefits from the cost savings. (Dkt. No. 548 at 8, citing Dkt. No. 538 at 3.) Relying on its argument regarding the lack of legal error in the given CSI, CommScope urges that the proposal could not be a "substantially correct statement of law" because the cost-savings approach must be based on the use made by CommScope as the accused infringer and hypothetical willing licensee. (*Id.* at 9.) Moreover, it argues, the charge as a whole covered TQ Delta's damages model such that the charge did not "seriously impair" TQ Delta's ability to present its damages claim. (*Id.*) Lastly, CommScope clarifies that its objection and subsequent proposed alternation to the CSI made clear that the cost-savings approach is only appropriate when other approaches would be difficult to apply, *Hanson*, 718 F.2d at 1081; and CommScope says it did not agree with TQ Delta's proposed modifications as TQ Delta argues. (Dkt. No. 562, citing Dkt. No. 555 at 2–3.)

The Court has already rejected TQ Delta's legal error argument. It now rejects this argument as well. The Court has "substantial latitude in crafting jury instructions." *Kanida v. Gulf Coast Medical Personnel LP*, 363 F.3d 568, 578 (5th Cir. 2004) (internal citations omitted). It was not error to decline to genericize the beneficiary of cost savings because the Court applied legal precedent in determining that the relevant cost savings were those to CommScope as the defendant and accused infringer. As already noted, the Court instructed the Jury that TQ Delta's damages model employed a cost-savings approach, and that it was free to apply TQ Delta's methodology. TQ Delta's damages model was therefore covered in the charge as a whole, and the charge did not materially impair TQ Delta's ability to present its damages claim.

ii. Dr. Becker's Testimony

The Court may grant a new trial based on an erroneous evidentiary ruling when the error prejudiced a substantial right of the moving party. *Network-1 Techs. v. Hewlett-Packard Co.*, No. 6:13-CV-00072-RWS, at *10 (E.D. Tex. May 7, 2021); *Munn v. Algee*, 924 F.2d 568, 571 (5th Cir. 1991); Fed. R. Civ. P. 61. Before trial, TQ Delta moved to strike the opinion of CommScope's damages expert, Dr. Becker, that the DSL chip included in the accused customer premises equipment ("CPE") products is the smallest saleable patent practicing unit ("SSPPU") because that opinion was not supported by any testimony or opinions of a technical expert. (*See* Dkt. Nos. 345, 382, 427.) This motion to strike was denied. (Dkt. No. 496 at 5.) TQ Delta argues that the Court committed further legal error by allowing Dr. Becker's opinion to be presented to the Jury. TQ Delta says this prejudiced it such that it is entitled to a new trial. (Dkt. No. 538 at 4, 11–13.) The Court disagrees for the reasons set forth below.

At trial, Dr. Becker opined that the SSPPU is the DSL chip and that damages should be a running royalty of 1.57% to 2.91% of the selling price of the DSL chip itself, rather than the full

DSL chipset. (Dkt. No. 538 at 4, citing Dkt. No. 533 at 73:19-24; 96:13-97:5; 131:25-132:3; 141:14-143:15.) Further, Dr. Becker "confirmed he based his damages opinion on his understanding that all the infringement of the accused products occurred only in the DSL chip." (*Id.*, at 11, citing Dkt. No. 533 at 131:25-132:3.) TQ Delta asserts (as it did in its pretrial motion) that Dr. Becker's SSPPU opinion was not properly premised on purported discussions Dr. Becker had with CommScope's technical experts, as none of these technical experts disclosed any opinion in their reports that would support Dr. Becker's position. (*Id.* at 11–12.) At trial, Dr. Becker admitted that he did not have the ability to make the SSPPU analysis on his own, and he acknowledged that CommScope's technical experts did not testify that the DSL chip is the SSPPU or that they had any discussions with Dr. Becker about the SSPPU. (*Id.* at 11, citing Dkt. No. 533 at 142:14-25; 143:1-15.)

TQ Delta acknowledges that it is permissible for Dr. Becker to rely on the opinions of CommScope's experts; however, it argues that "he cannot rely on a 'black box' of undisclosed and unexplained opinions." (*Id.* at 11–12, citing, *e.g.*, *Finalrod IP, LLC v. Endurance Lift Sols., Inc.*, No. 2:20-cv-00189, at *8 (E.D. Tex. Oct. 20, 2021) (precluding plaintiff's damages expert from making statements about plaintiff's technical expert's opinion regarding non-infringing alternatives provided on a phone call because the technical expert "never disclosed that opinion or disclosed any analysis to properly support that opinion".) TQ Delta argues that because CommScope's technical experts presented no opinions about SSPPU to the Jury, TQ Delta had no opportunity to cross-examine them on such opinions; therefore, the SSPPU opinion and following conclusion that the DSL chip should be the base for the royalty was prejudicial. (*Id.* at 12.) TQ Delta also contends that this prejudice was compounded because Dr. Becker's unsupported testimony allowed the Jury to undervalue TQ Delta's damages by starting with a smaller royalty

base. (*Id.*) In TQ Delta's view, it is entitled to a new trial on damages "at which CommScope is not allowed to base its royalty damages theory on just the DSL chip." (*Id.* at 13, internal citations omitted.)

In response, CommScope contends that Dr. Becker's complained of conclusion—that the royalty should be based on the price of only the DSL chip—was not premised on the DSL chipset being the SSPPU. (Dkt. No. 548 at 9.) Rather, Dr. Becker based his damages analysis on the license agreements Aware executed around the time of the hypothetical negotiation date, establishing that Aware had a practice of licensing on a chipset basis and explaining the impact of those agreements on the hypothetical negotiation.[10] (*Id.* at 9–10.) Dr. Becker testified that he relied on Dr. Ransom for technical comparability, who concluded that the [redacted] chips were technically comparable to the accused Broadcom chipset. (*Id.*, citing Dkt. No. 533 at 87:10–88:8.) CommScope argues that this comparable license analysis was the basis for the conclusion that TQ Delta complains about, and Dr. Becker made clear at trial that he did not need to rely on the SSPPU to conclude that the Aware license agreements were comparable. (Dkt. No. 562 at 4, citing Dkt. No. 533 at 143:16–144:5 ("I don't need the smallest saleable patent-practicing unit conclusion to reach the conclusion that the Aware licenses are relevant. And so there was no need to spend time with that in my testimony because it's not indicative or determinative of the conclusions I reach"); 144:15–23.)

As to the arguments addressing the SSPPU opinions themselves, CommScope argues these are just "repackaged *Daubert* arguments[.]" (*Id.* at 10, citing Dkt. No. 493 at 141:27–142:8 ("I am going to deny the Plaintiff's Motion. I think there's enough in the record to make it clear that [the

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[10] CommScope explains that at trial, Dr. Becker presented a comparable license approach based on Aware's licenses [redacted] which were the closest agreements in time to the hypothetical negotiation date. (Dkt. No. 548 at 10, citing Dkt. No. 533 at 81:16–83:2, 86:7–11, 87:10–88:8, 92:25–93:13.) Dr. Becker testified that these licenses covered DSL chipsets, and the agreements contemplated that those chipsets would be integrated in customer premises equipment. (*Id.*, citing Dkt. No. 533 at 89:17–24, 91:9–92:3, 93:7–11.)

DSL chipset] is probably what is the SSPPU.”).) It urges that it is improper to use a motion for new trial as a renewed *Daubert* challenge, and that TQ Delta’s arguments related to the reliability of Dr. Becker’s opinions regarding the SSPPU should be rejected on the same grounds. (*Id.* at 11, citing *Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d 1255, 1264 (Fed. Cir. 2013).)

CommScope goes on to argue that even if the Court were to reconsider TQ Delta’s arguments about the SSPPU opinions, they are still without merit. (*Id.*) It challenges TQ Delta’s allegation that the Jury heard no testimony or evidence that supports Dr. Becker’s analysis; indeed, it points to testimony by Dr. Cimini and Dr. Ransom that TQ Delta’s own technical experts pointed solely to functionality found within the Broadcom chipset in connection with infringement. (*Id.*, citing Dkt. 532 at 154:7–155:4, 155:5–20, 233:22–234:20.) CommScope also argues that its technical experts testified at trial about the information which Dr. Becker subsequently explained he had confirmed with these same experts during expert discovery. (*Id.*, citing Dkt. 533 at 142:14–25; Dkt. 382 at 5.) Further, CommScope notes that Dr. Becker testified that he specifically discussed with the technical experts the inventive elements of what TQ Delta practices and that they were found within the Broadcom chipset. (*Id.* at 12, citing Dkt. 533 at 142:14–25.) Since these opinions were in the technical experts’ reports, argues CommScope, Dr. Becker was entitled to rely on that information in forming his SSPPU opinion. (*See id.* at 12 n.5.)

CommScope is correct that the Court has already ruled before trial began on the admissibility of Dr. Becker’s SSPPU opinion. The Court found that there was enough in the record to support the position that the chipset was the SSPPU. This was in response to the very same arguments now renewed by TQ Delta. (Dkt. No. 493 at 141:27–142:8.) The Court finds no compelling reason in TQ Delta’s briefing to alter that ruling now. Further, CommScope has pointed to testimony where Dr. Becker testified as to the content of those conversations with the

technical experts.[11] CommScope's technical experts were present at trial and subject to cross-examination by TQ Delta. The SSPPU opinion was not "unsupported" as TQ Delta claims, much less so devoid of support so as to justify a new trial on damages.

Further, TQ Delta takes issue with Dr. Becker's conclusion that the royalty should be based on the DSL chipset, and it attacks the SSPPU opinion as a basis for that conclusion. However, Dr. Becker made clear to the jury that his SSPPU opinion did not affect his conclusions.[12] (*See* Dkt. No. 533 at 144:15–23 ("Q. … Whether or not the chip, the semiconductor chip, is the smallest saleable patent-practicing unit, does that affect your conclusions and analysis in this case in any way or change what you've told the jury? A. No.").)

In sum, Dr. Becker fully explained his comparable license approach and resulting conclusion that the DSL chipset should be the royalty base, and he further explained the independence of this analysis from the SSPPU opinion. There is enough in this record, even if the Court finds that the SSPPU opinion was unsupported (which it does not), to independently support Dr. Becker's conclusion that the DSL chipset should be the royalty base. Since Dr. Becker's conclusion regarding the royalty base did not hinge on the SSPPU opinion, there is no prejudice; much less sufficient prejudice to warrant a new damages trial.

B. Motion for New Trial on Validity of '835 Patent

TQ Delta next contends that the Court improperly struck four paragraphs from Dr. Madisetti's rebuttal report on invalidity concerning the '835 Patent, resulting in material prejudice

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[11] For example, Dr. Becker testified that "they told me that all of the sort of inventive aspects of the patents that were being accused by TQ Delta's experts were found in the Broadcom chip." (Dkt. No. 562 at 4, citing Dkt. 533 at 142:14-23.)

[12] TQ Delta points out that Dr. Becker testified to the contrary. (Dkt. No. 555 at 4, citing Dkt. No. 533 at 131:25-132:3 ("Q. You believe, don't you sir, it's your testimony, and it's the basis for your opinion that the [SSPPU] in this case is the DSL chip, don't you? A. I do.") The Court notes that this testimony came before he clarified that his SSPPU opinion does not affect his conclusions in the case, and it was in response to a compound and potentially confusing question. In any case, it is left to Jury to weigh reliability of testimony.

which would support a new trial. (Dkt. No. 538 at 13.) Specifically, the stricken paragraphs in Dr. Madisetti's rebuttal report expressed his opinion that prior art reference G.992.1's DRA_Swap_Request and DRA_Swap_Reply messages do not meet the "flag signal" requirement of claim 10 of the '835 Patent because they do not "indicate" when the updated FIP setting is to be used but instead *set forth* the change in time in the message itself. (Dkt. No. 538 at 13, emphasis in original.) The Court struck these paragraphs because they conflicted with the Court's claim construction for "flag signal"; which is: a "signal used to indicate when an updated FIP setting is to be used (the signal does not include the FEC codeword counter value upon which the updated FIP setting is to be used)." (*See* Dkt. No. 496 at 4; Dkt. No. 169 at 91.)

TQ Delta urges that Dr. Madisetti's opinions were in fact consistent with the positive portion of the Court's construction of "flag signal" requiring a "signal used to *indicate* when an updated FIP setting is to be used." (Dkt. No. 538 at 14, quoting Dkt. No. 169 at 91 (emphasis added).) The stricken opinions explained Dr. Madisetti's position that the prior art reference's DRA_Swap_Request and DRA_Swap_Reply messages cannot meet the Court's construction because they themselves include information that sets forth, rather than indicates, when the updated FIP setting is to be used. (*Id.* at 14, 14 n.5, citing Dkt. No. 342-3 (Madisetti Report).) TQ Delta asserts that this is reasonable because the use of "flag signal" in the '835 Patent specification and related claim language showing that the switching time is "predefined," rather than specified in a message during operation.[13] (*Id.* at 14, citing Tr. Ex. 6 ('835 Patent), at 19:14-30 and at claim 8.)

[13] TQ Delta argues that the Court recognized this same distinction: "This usage of 'pre-defined' and 'following' demonstrates that a 'flag signal' does not itself set forth a change time but rather is merely an indication that the updated FIP setting / interleaver parameter value should be used at some juncture that is pre-defined in relation to when the flag signal is received." (Dkt. No. 538 at 14, quoting Dkt. No. 169 at 90.)

Further, TQ Delta alleges that this "erroneous" exclusion was materially prejudicial because it prevented Dr. Madisetti from presenting conclusive evidence to the Jury that G.992.1 did not disclose a "flag signal" because those messages "set forth a change time" as opposed to "flag signal" as construed, requiring an indication instead. (*Id.* at 14–15.) Had these paragraphs not been excluded, TQ Delta surmises that the Jury "would not have had substantial evidence upon which it could have reasonably found that G.992.1 anticipates claim 10 of the '835 Patent." (*Id.* at 15.)

In response, CommScope contends that this portion of the Motion is yet another attempt by TQ Delta to inappropriately re-argue *Daubert* arguments, and the request for new trial on the invalidity of the '835 Patent should be denied on this reason alone. (Dkt. No. 548 at 14.) However, should the Court consider the merits of the argument, CommScope argues that the same ruling should result because Dr. Madisetti improperly provided his own construction for the term "flag signal." (*Id.*) In particular, Dr. Madisetti stated that it was his opinion "that a flag signal is required to be a flag signal that has no information." (*Id.*, citing Dkt. 342 at 1 (quoting Dkt. 342-3 at ¶ 71).) CommScope asserts that this opinion tracked TQ Delta's rejected proposed construction for the term "flag signal," and that he used his own claim construction as a basis to distinguish the prior art. (*Id.* ("*Compare* Dkt. 169 at 87, 90 *with* [Dkt. No. 342-3 at ¶ 72]"); citing Dkt. No. 342-3 at ¶ 72.)

Moreover, CommScope argues, the exclusion of these four paragraphs of a report is not prejudicial, and does not warrant a new trial. Indeed, Dr. Madisetti offered a different opinion at trial that the "flag signal" limitation as construed was not med by the prior art. (*Id.*, citing Dkt. No. 533 at 168:8–19.) As CommScope points out, TQ Delta was able to cross-examine Mr. McNair on his opinions regarding invalidity, though it chose not to address the "flag signal" limitation

during that cross-examination. (*Id.* at 15, citing *Cardsoft, Inc. v. Verifone Holdings, Inc.*, No. 2:08-cv-98-RSP (E.D. Tex. Sept. 30, 2013) ("[Defendant] did not cross-examine him on the basis for his opinion, and therefore the jury was free to accept or reject this opinion evidence.").) Finally, CommScope argues that Mr. McNair also opined that the flag signal was found in a second reference, the Texas Instruments contribution (SC-060, Tr. Ex. 57).[14] (*Id.*, citing Dkt. 532 at 311:18–22, 327:10–14.) Since Dr. Madisetti's excluded opinions did not address this second reference, CommScope argues that exclusion did not prejudice TQ Delta.

The Court is unpersuaded by TQ Delta's argument that the exclusion of the specified four paragraphs of Dr. Madisetti's rebuttal report have caused a level of prejudice necessitating a new trial. As noted above, these arguments are properly made at the *Daubert* stage. *See Versata Software*, 717 F.3d at 1264. (post-trial briefing is not the appropriate context for renewing *Daubert* arguments). Even so, the Court previously ruled that Dr. Madisetti construed the term "flag signal" in a manner contrary to the Court's construction. The Court finds no reason which demands a result contrary to that holding. (See Dkt. No. 169 at 91.) Further, as CommScope points out, there was another basis upon which the Jury could determine that prior art (the Texas Instruments contribution) met the term "flag signal" as construed. Therefore, there was no prejudicial error warranting a new trial regarding the validity of the '835 Patent.

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[14] In TQ Delta's Reply, it makes a new argument that was not included in its Motion; i.e., that Dr. McNair provided no motivation to combine G.992.1 and SC-060 such that his obviousness theory could not serve as a basis for the verdict. (Dkt. No. 555 at 5.) As CommScope points out, TQ Delta is precluded from asserting a new argument in its Motion. (Dkt. No. 562 at 5, citing *Wantou v. Wal-Mart Stores Tex.*, 2020 U.S. Dist. LEXIS 147595, at *47 (E.D. Tex. Mar. 12, 2020) ("It is black-letter law that arguments raised for the first time in a reply brief are waived 'as a matter of litigation fairness and procedure.'") The Court also notes that TQ Delta separately filed a motion for JMOL of validity of the '686 and '835 Patents, and while it argued that there was no motivation to combine prior art references for the '686 Patent, it made no such argument for the '835 Patent. To be clear, the Court does not consider this argument. Even if it had considered it, the bare assertion that there was no motivation to combine is insufficient by itself and is not supported by evidence.

C. Conditional Motion for New Trial on Additional Damages

Lastly, TQ Delta argues that to the extent the Court grants one or more of TQ Delta's motions for JMOL of infringement of the '008 Patent (Dkt. No. 539), no invalidity of the '686 Patent or no invalidity of the '835 patent (Dkt. No. 537), or TQD's motion for a new trial on validity of the '835 Patent, the Court should also grant a new trial to determine the additional damages that would be due for CommScope's infringement of the additional patent(s). (Dkt. No. 538 at 15.) It argues that a new trial on such damages would be warranted because the jury's verdict did not compensate TQD for CommScope's infringement of any of those patents. (*Id.*)

Regarding the JMOLs of no invalidity of the '686 Patent and the '835 Patents, the Court has already denied that motion. (*See* Dkt. No. 566.) As such, this request is moot. As a part of this Order, the Court denies TQ Delta's motion for new trial on the validity of the '835 Patent, so that request is denied herein. As to the JMOL of infringement of the '008 Patent, that request for relief is requested in that separate motion (Dkt. No. 539), and shall be considered when the Court addresses that Motion.

IV. CONCLUSION

Having considered the parties' briefing and the entire record, the Court is persuaded that CommScope introduced substantial evidence which is adequate to support the Jury's verdict such that no new trial on damages or invalidity of the '835 Patent is warranted. Accordingly, of TQ Delta's Motion (Dkt. No. 539) is **DENIED** in its entirety. The parties are directed to jointly prepare a redacted version of this Order for public viewing and to file the same on the Court's docket as an attachment to a Notice of Redaction within five (5) business days of this Order.

So ORDERED and SIGNED this 6th day of September, 2023.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC, *Plaintiff*, v. COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS US HOLDINGS, INC., ARRIS SOLUTIONS, INC., and ARRIS ENTERPRISES, LLC, *Defendants*.	§ § § § § § § § § § § § §	CIVIL ACTION NO. 2:21-CV-00310-JRG [redacted]

MEMORANDUM OPINION AND ORDER

Before the Court is Defendants CommScope Holding Company, Inc., CommScope Inc., Arris International Limited, Arris Global Ltd., Arris US Holdings, Inc., Arris Solutions, Inc., and Arris Enterprises, LLC's (collectively, "CommScope") Renewed Motion for Judgment as a Matter of Law (the "Motion"). (Dkt. No. 541.) In the Motion, CommScope requests that the Court enter judgment as a matter of law that Plaintiff TQ Delta, LLC ("TQ Delta") breached its contractual obligation to grant a license on fair, reasonable, and non-discriminatory ("FRAND") terms, and seeks a new trial limited to the question of the appropriate damages owed to CommScope for the alleged breach. (*Id.* at 1.) Having considered the arguments and briefing, the Court is of the opinion that the Motion should be and hereby is **DENIED**.

I. BACKGROUND

On August 13, 2021, TQ Delta filed the above-captioned case against CommScope asserting infringement of certain patents. (*See* Dkt. No. 1.) CommScope answered the Complaint on October 22, 2021, asserting the defenses of invalidity and noninfringement. (*See* Dkt. No. 17.) Additionally, CommScope asserted a breach of contract counterclaim. (*Id.* at 37.) CommScope

alleged that TQ Delta entered into a contract with the International Telecommunications Union ("ITU"), and that under that contract, TQ Delta had an irrevocable obligation to permit use of its allegedly essential patents, including the Asserted Patents, by manufacturers like CommScope on FRAND terms. (*Id.*) Specifically, in its contract with the ITU, TQ Delta promised it would "grant a license to an unrestricted number of applicants on a worldwide, non-discriminatory basis and on reasonable terms and conditions to make, use, and sell implementations of the" ITU-T Recommendation." (Dkt. No. 541 at 3, citing Ex. 68 at 2.) CommScope claimed that TQ Delta breached this contractual agreement. (Dkt. No. 17 at 37.) TQ Delta does not deny that its standard essential patents ("SEPs") are subject to a FRAND commitment with the ITU. (Dkt. No. 545 at 2.)

On March 17, 2023, a jury trial commenced in this case. After the close of evidence on March 23, 2023, the Court took up matters from both sides under Federal Rule of Civil Procedure 50(a), where CommScope moved for judgment as a matter of law that TQ Delta breached its FRAND obligations imposed by its contract with the ITU. (Dkt. No. 533 at 238:6–240:5.) Specifically, CommScope argued that TQ Delta failed to offer licenses to its patents to CommScope on FRAND terms. (*Id.* at 238:23–239:4.) The Court denied CommScope's 50(a) motion. (*Id.* at 249:6–11.)

On March 24, 2023, the Jury returned its verdict. (*See* Dkt. No. 508.) In pertinent part, the Jury found that CommScope failed to prove that TQ Delta breached its contractual duty to grant licenses regarding its patents declared to the standard on FRAND terms. (*Id.* at 8.) Further, the Jury found that CommScope infringed the asserted claims of the '881 Patent, the '686 Patent, the '048 Patent, the '835 Patent, the '411 Patent, and the '354 Patent. (*Id.* at 4.) The Jury also found, however, that the asserted claims of the '686 Patent and the '835 Patent were invalid. (*Id.* at 5.) The Jury assessed damages against CommScope in the amount of $11,125,000 for its infringement

of the four patents found infringed and not invalid.[1] (*See id.* at 7.) On May 3, 3023, the Court entered final judgment on the verdict. (Dkt. No. 513.) CommScope now renews its 50(a) JMOL, seeking judgment as a matter of law that TQ Delta breached its contractual obligation and seeking a new trial limited to the question of appropriate damages owed to CommScope for TQ Delta's alleged breach. (Dkt. No. 541 at 1.)

II. LEGAL STANDARD

Upon a party's renewed motion for judgment as a matter of law following a jury verdict, the Court asks whether "the state of proof is such that reasonable and impartial minds could reach the conclusion the jury expressed in its verdict." FED. R. CIV. P. 50(b); *Am. Home Assur. Co. v. United Space Alliance*, 378 F.3d 482, 487 (5th Cir. 2004). "The grant or denial of a motion for judgment as a matter of law is a procedural issue not unique to patent law, reviewed under the law of the regional circuit in which the appeal from the district court would usually lie." *Finisar Corp. v. DirectTV Group, Inc.*, 523 F.3d 1323, 1332 (Fed. Cir. 2008). "A JMOL may only be granted when, 'viewing the evidence in the light most favorable to the verdict, the evidence points so strongly and overwhelmingly in favor of one party that the court believes that reasonable jurors could not arrive at any contrary conclusion.'" *Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d 1255, 1261 (Fed. Cir. 2013) (quoting *Dresser-Rand Co. v. Virtual Automation, Inc.*, 361 F.3d 831, 838 (5th Cir. 2004)).

Under Fifth Circuit law, a court is to be "especially deferential" to a jury's verdict, and must not reverse the jury's findings unless they are not supported by substantial evidence. *Baisden v. I'm Ready Productions, Inc.*, 693 F.3d 491, 499 (5th Cir. 2012). "Substantial evidence is defined as evidence of such quality and weight that reasonable and fair-minded men in the exercise of

[1] The '881 Patent, the '048 Patent, the '411 Patent, and the '354 Patent were found infringed and not invalid. (*See* Dkt. No. 508 at 4–5.)

impartial judgment might reach different conclusions." *Threlkeld v. Total Petroleum, Inc.*, 211 F.3d 887, 891 (5th Cir. 2000). A motion for judgment as a matter of law must be denied "unless the facts and inferences point so strongly and overwhelmingly in the movant's favor that reasonable jurors could not reach a contrary conclusion." *Baisden*, 393 F.3d at 498 (citation omitted). However, "[t]here must be more than a mere scintilla of evidence in the record to prevent judgment as a matter of law in favor of the movant." *Arismendez v. Nightingale Home Health Care, Inc.*, 493 F.3d 602, 606 (5th Cir. 2007).

III. DISCUSSION

Under Texas law, a party asserting breach of contract must prove: "(1) the existence of a valid contract; (2) that the [party] performed or tendered performance; (3) that the other party breached the contract; and (4) that the party was damaged as a result of the breach." *City of Dall. v. Delta Air Lines, Inc.*, 847 F.3d 279, 287 (5th Cir. 2017) (internal citations omitted). CommScope argues in its Motion that it demonstrated that each element of its breach of FRAND claim was met during trial, and urges that a reasonable jury could not have found otherwise. (Dkt. No. 541 at 2.) TQ Delta responds first that CommScope did not present evidence which would compel a reasonable jury to find that TQ Delta did not meet its FRAND obligations. (Dkt. No. 545 at 2.) Even if it had, TQ Delta argues that CommScope failed to prove harm, thereby eliminating any possibility of breach and any remedy. (*Id.*)

A. CommScope Did Not Establish Harm

CommScope argues that it proved that TQ Delta's breach harmed CommScope. (Dkt. No. 541 at 8.) It contends that if TQ Delta had made an offer on FRAND terms for the declared essential patent portfolio, "CommScope *could* have accepted that offer and there would have been no need for this litigation." (*Id.*) (emphasis added). Further, CommScope points to the testimony of Mr.

Wauters, its corporate representative, that CommScope actively made its own FRAND offers to try to negotiate itself out of the business disruptions caused by the litigation. (*Id.*, citing Dkt. No. 528 at 283:11–23.) CommScope additionally notes that [redacted] (*Id.* at 8 n.3, citing Dkt. No. 541-12 at 6–7.) Lastly, the Motion vaguely mentions "sales lost to competitors" without elaboration and without citation to the record. (*Id.*)

TQ Delta responds that CommScope failed to offer any evidence of pecuniary loss with any degree of certainty at trial. (Dkt. No. 545 at 3.) TQ Delta also notes that Mr. Wauters did not say that CommScope's business was disrupted or that the lawsuit took resources away from focus areas of the company.[2] (*Id.* (quoting Dkt. No. 530 at 283:11-23) (cited by CommScope at Dkt. No. 541 at 8).) Additionally, TQ Delta points out that under Texas law, damages for business interruption "are measured by the amount of profits lost due to the interruption," and that the "loss amount must be shown by competent evidence with reasonable certainty." *JPMorgan Chase Bank, N.A. v. Prof'l Pharmacy II*, 508 S.W.3d 391, 429 (Tex. App.–Fort Worth 2014). It urges that Mr. Wauters' testimony fails to meet this standard. (*Id.* at 4.) Further, TQ Delta notes that its own general reference to its own potential litigation costs at trial is not evidence of *CommScope's* damages. (*Id.*, emphasis in original.)

Lastly, TQ Delta asserts that CommScope did not show that it was entitled to nominal damages because it did not take the position that its harm was non-economic in nature. (*Id.* at 5 n.1, citing *Loeb-Defever v. Strategic Constr., Ltd.*, 2022 U.S. Dist. LEXIS 124597, at *15–18 (S.D.

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[2] "[O]ur intention was to try to negotiate a deal with them so ultimately we wouldn't have to litigate it; we wouldn't end up in a courtroom like this. So our intention was to try to come up with a compromise with them, and that's why we offered the lump sum plus the other licensing arrangement in that offer. And also, frankly, we want to keep -- stay focused on designing and building products. Right? We don't want our business to be disrupted on events like this. And, I mean, this obviously can take a lot of resources away from our focus areas inside of our company, and so that definitely was the intent of making that offer over to TQ Delta." (Dkt. No. 530 at 283:11-23.)

Tex. July 14, 2022).) CommScope replies that TQ Delta is “simply rehashing issues previously decided by the Court during the informal charge conference and in the verdict form.” (Dkt. No. 553 at 3.) CommScope additionally notes that the Court instructed the Jury on nominal damages (*see* Dkt. No. 534 at 72:18–25) and made clear that a “contractual obligation where mere proof of the making and breach fully proved plaintiff’s cause of action” would entitle the plaintiff to at least nominal damages. (*Id.*, quoting *Versata Software, Inc. v. Internet Brands, Inc.*, 2012 U.S. Dist. LEXIS 105585, at *10–12 (E.D. Tex. Jul. 30, 2012).)

The Court concludes that the CommScope put on no concrete evidence of harm or damages as a result of the alleged breach of FRAND. A reasonable jury could have concluded that CommScope was not harmed by any alleged breach based on the record produced at trial. As TQ Delta points out, CommScope only points to “speculative business disruption untethered to any actual damages,” unsupported attorney argument via briefing of lost sales to unknown competitors, and its reference to litigation expenses on documents of TQ Delta’s that were never presented to the Jury. (*See* Dkt. No. 545 at 4.)

The parties dispute whether CommScope was entitled to recover nominal damages when it asserted only economic harm. CommScope points to case law that discusses the availability of nominal damages in the context of a plaintiff proving the making of a contract and breach of the same. (*See* Dkt. No. 553 at 3–4, citing *Versata Software*, 2012 U.S. Dist. LEXIS 105585, at *10–12.) In any event, the Court instructed the Jury that nominal damages were recoverable in the event of a breach, and there was no objection to this instruction during the formal charge conference. (Dkt. No. 534 at 72:18–25; 15:4–18.) Therefore, the Jury could have found breach even if there was no harm in accordance with that instruction. For this reason, the Court next evaluates whether

there was sufficient basis for the Jury to find that there was no breach of TQ Delta's FRAND obligations.

B. There Was Sufficient Evidence for the Jury to Conclude There Was No Breach

CommScope relies on two main points to demonstrate that no reasonable jury could have found that TQ Delta did not breach its FRAND obligations imposed by its contract with the ITU. First, it argues that TQ Delta licensed CommScope's DSL equipment maker competitors at a rate substantially less than any of TQ Delta's offers to CommScope for the same license. (*See* Dkt. No. 541 at 4–5.) Second, CommScope contends that because the Jury's damages award resulted in an "effective royalty" that was much lower than TQ Delta's offers, the Jury could only have found that TQ Delta breached its FRAND obligations. (*Id.* at 1; 5–8.)

i. TQ Delta's Other Licenses

After acquiring the Asserted Patents, TQ Delta published its FRAND royalty rates of $0.60 to $1.35 per licensed product per standard (depending on the number of the following standards incorporated into each licensed product: VDSL2, G.Bond, and G.Inp).[3] (Dkt. No. 541 at 4, citing Dkt. No. 541-11; *see also* Dkt. No. 545 at 11.) It then entered licenses with DSL equipment makers [redacted]. [redacted] (*Id.*, citing Exs. 36-A, 36-B, 37, 38-A, 38-B, 40; Dkt. No. 528 at 99:1–102:2, 110:6–114:2, 122:22–124:8, 128:1–132:7.) Though TQ Delta asserted in trial that [redacted] were licensed at a [redacted]

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[3] TQ Delta purchased the Asserted Patents from Aware, Inc. ("Aware"), which had previously entered into a contractual obligation to the ITU commensurate with TQ Delta's. (Dkt. No. 541 at 3.) CommScope contends that when TQ Delta purchased the patent portfolio, it inherited the FRAND obligations and existing licenses reflecting those obligations. (*Id.*) In any event, TQ Delta signed its own obligation with the ITU, and does not dispute that (as explained *supra*).

per-unit rate, CommScope urges—as it did during trial—that was not the case. (*Id.*) Instead, CommScope points to discounts, or "adjustments," to the standard rate resulting in a per-unit rate of [redacted]. (*Id.*, citing Dkt. No. 528 at 105:18–20, 120:8–121:4; Tr. Vol. 5, Dkt. No. 533 at 153:10–155:9.) As explained further *infra*, the CommScope insists that the Jury found [redacted] to be a reasonable "effective rate," and further insists that this amount is consistent with the average between these per-unit rates for TQ Delta's other licensees. (*Id.*)

TQ Delta's first offer to CommScope, prior to litigation, was a rate of [redacted] per licensed products for the relevant accused standards—VDSL2, G.INP, and G.bond (designed to operate with VDSL2). (*Id.* at 5, citing Exs. 124B, 135B.) CommScope argues that this offer was not FRAND because CommScope's DSL equipment maker competitors all paid substantially less than [redacted] (*Id.*) It asserts that TQ Delta "sought to commercially disadvantage CommScope by seeking to charge five times the alleged standard rate for the G.INP standard that CommScope's [redacted] had paid." (*Id.*, citing Dkt. No. 532 at 114:7–18.) After litigation commenced, TQ Delta raised its demand to [redacted] per licensed product; during trial, the demand was raised to [redacted] per licensed product. (*Id.*, citing Dkt. No. 532 at 112:3–8; 112:19–113:3.) These post-litigation offers covered only five of the Asserted Patents (those subject to a FRAND commitment). (*Id.*) CommScope put on evidence of these offers at trial and argued that TQ Delta's offers breached its FRAND obligations.

In response, TQ Delta argues that the Jury was not required to accept what it views as CommScope's mischaracterization of the rates given to TQ Delta's other licensees. (Dkt. No. 545 at 5–6.) Regarding the [redacted] agreements, TQ Delta put on evidence that they included an [redacted]

[redacted] (*Id.* at 6, citing Ex. 36-B at TQD_TX00313568; Ex. 37 at TQD_TX- 00044462; Dkt. No. 528 at 104:13-19, 106:11-107:5, 108:20-109:7, 115:11-118:12.) Regarding the [redacted] agreement, TQ Delta argues that CommScope mischaracterized that license as a worldwide license when it was not. (*Id.*, citing Dkt. No. 533 at 153:10-155:9.) In TQ Delta's view, the Jury could have concluded that there was [redacted] did not compensate TQ Delta for approximately [redacted] (which CommScope included in its calculation of the royalty rate). (*Id.*, citing Trial Exs. 38-A at TQD_TX00491591; 38-B; Dkt. No. 528 at 130:1-131:24, 132:12-16.)

TQ Delta further points out that the non-discriminatory aspect of the FRAND obligation applies to similarly situated competitors who have been similarly willing to negotiate licenses in good faith. (*Id.* at 6–7, citing Ex. 68; Dkt. No. 528 at 71:3-16, 149:10-151:4, 152:13-154:9, 185:8-12, 186:7-25; Dkt. No. 530 Tr. at 205:21-207:4.) TQ Delta points to important differences in negotiations between CommScope on the one hand, and with [redacted] on the other. (*Id.* at 7.) At trial, TQ Delta put on evidence of differences relating to good faith negotiations, early negotiations, and expiration of some patents that resulted in adjustments for its other licensees but did not apply to CommScope. (*Id.* at 7–8, citing Dkt. No. 528 at 31:18-32:4, 117:21-118:7-21, 128:18-25, 163:13-165:6, 167:23-171:7, 173:13-19, 174:18-177:19, 178:14-25, 187:1-9; Dkt. No. 532 at 116:11-12, 123:12-25.) TQ Delta contended at trial that CommScope was not a willing licensee and failed to negotiate in good faith.[4] (*Id.* at 7–8.) TQ Delta's damages expert also

[4] In particular, TQ Delta put on evidence that CommScope did not negotiate in good faith because: (1) it did not approach TQ Delta for a license, (2) dragged out negotiations over years, (3) refused to provide technical and unit sales information to TQ Delta, and (4) its counteroffer required TQ Delta to enforce CommScope's patents in order to recover a substantial portion of the royalties. (Dkt. No. 545 at 7–8, citing Dkt. No. 528 at 14:22-21:16, 26:17-29:17, 32:8-43:20, 160:21-25, 169:6-10, 171:8-172:4; Dkt. No. 532 at 58:12-22; Dkt. No. 530 at 247:3- 252:11.)

testified at trial that its offer to CommScope was reasonable in comparison with TQ Delta's other licenses. (*Id.* at 8, citing Dkt. No. 532 at 9:11-13:25.)

The Court finds that substantial evidence supports the Jury's determination that there was no breach of TQ Delta's contractual obligations. Contrary to CommScope's argument, the Jury was free to credit TQ Delta's evidence over that of CommScope.

TQ Delta put on a myriad of evidence that [redacted] were not similarly situated to CommScope such that TQ Delta was not required to offer CommScope those same adjustments to meet its FRAND obligations. Take [redacted], for example, whom CommScope asserts is its closest competitor and argues is similarly situated. (*See* Dkt. No. 553 at 1.) TQ Delta put on evidence that [redacted] was offered [redacted] that CommScope was, but was granted adjustments because [redacted] was [redacted] (*See* Dkt. No. 558 at 1–2; *see also infra*, n.6.) In contrast, TQ Delta put on evidence that CommScope was not an early mover, delayed negotiations approximately 10 years, withheld information, made an unreasonable counteroffer,[5] and sold [redacted] in infringing products in the U.S. without a license.[6]

The evidence differentiating license negotiations between [redacted] and CommScope is only one example—TQ Delta put on evidence distinguishing [redacted] from CommScope as well. (*See supra* at 8.) Additionally, Dr. Putnam testified that TQ Delta's offer to CommScope was reasonable and non-discriminatory when compared to TQ Delta's other licenses. (*See* Dkt. No.

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[5] TQ Delta also put on evidence that it was willing to provide CommScope adjustments like those it gave to other licensees if CommScope provided it data necessary to apply the adjustments. (Dkt. No. 558 at 2.)

[6] *Compare* Dkt. No. 528 at 117:21–118:21, 167:23–171:7, 173:13–19, 178:14–22, 187:1-9; Dkt. No. 532 at 116:11-12, 123:12-25 (evidence regarding [redacted]); *with* Dkt. No. 528 at 14:22-21:16, 26:17- 29:17, 32:8-43:20, 106:20-107:5, 115:20-122:21, 160:18-22, 169:6-10, 171:8-173:8; Dkt. No. 530 at 247:3-252:11; Dkt. No. 532 at 58:12-22; Dkt. No. 533 at 116:9-117:2 (evidence regarding CommScope).

532 at 9:11-13:25, 26:23-25.) The Jury was free to credit TQ Delta's evidence showing it complied with its FRAND obligations, and to discredit CommScope's evidence that TQ Delta failed to comply with FRAND. Indeed, the Court finds that a reasonable jury could have found—as this Jury apparently did—that TQ Delta did not breach its FRAND obligations and that its offer of license to CommScope was commensurate with its offers to other licensees, accounting for differences in circumstances.

ii. Jury's Damages Award for Infringement

Next, CommScope urges that the Jury's award of $11,250,000 for the four patents found to be infringed, which corresponds to "a per-unit royalty of [redacted] is a reasonable royalty under the circumstances.[7] (Dkt. No. 541 at 1.) CommScope argues that this amounts to a finding of breach on behalf of TQ Delta—even though the Jury explicitly found that there was no breach of FRAND. It points to the instruction to the Jury that it "must make sure that any reasonable royalty determination takes into account TQ Delta's FRAND obligations." (*Id.* at 5, citing Dkt. No. 534 at 67:22–23.) CommScope further urges that Dr. Putnam, TQ Delta's damages expert, admitted that the rate TQ Delta sought to charge CommScope for the G.INP standard would violate FRAND "if that were an offered license." (*Id.* at 6, citing Dkt. No. 532 at 114:23–115:4.) It also argues that TQ Delta mistakenly assumed throughout trial that it could charge CommScope non-FRAND rates for its declared-essential patent portfolio, as demonstrated by Dr. Putnam's testimony. (*Id.*, citing Dkt. No. 532 at 115:2-19.)

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[7] CommScope calculated the [redacted] amount from a royalty base of [redacted] units of Accused Products. (Dkt. No. 541 at 7.) It additionally notes that the Jury's "effective reasonable royalty of [redacted] per product" is about a tenth of TQ Delta's demands of [redacted] per product. (*Id.*)

CommScope also contends that TQ Delta's proposed royalty rates (from [redacted] per product) were not FRAND because "TQ Delta failed to apportion its rates to the value of the patents, overlooked that the accused products are 'subject to other patent pools,' and overlooked that the accused products include features beyond those claimed in the patents, such as WiFi and fiber connection." (*Id.* at 7, citing Dkt. No. 533 at 194:6–12, 146:19–147:6; *Uniloc USA, Inc. v. Microsoft Corp.*, 632 F.3d 1292, 1318 (Fed. Cir. 2011).) Additionally, CommScope argues that all of the accused functionality was found only in the chipset, such that seeking to charge a percentage of the entire product was not FRAND.[8] (*Id.*)

In sum, CommScope asserts that the Jury's "finding" of [redacted] reasonable royalty per product—when taking into account the royalty base of [redacted] units and the award of $11,250,000 for four patents—is a rate consistent with those CommScope presented for [redacted] (which average to [redacted] per product). (*Id.*) CommScope notes this is also consistent with CommScope's application of the [redacted] agreement (concerning [redacted] to the [redacted] chipsets in the Accused Products in this case (which CommScope posits resulted in a royalty rate of [redacted] per product). (*Id.* at 7–8.) It concludes that the "jury's finding of a 'reasonable' royalty of [redacted] …demonstrates that TQ Delta's offers to CommScope were *not* reasonable, and therefore *not* FRAND[.]" (*Id.* at 8.)

TQ Delta dismisses CommScope's argument as baseless. (Dkt. No. 545 at 8.) First, it points out that the Jury was not asked to decide (and did not decide) whether [redacted], nor TQ Delta's other offers, were FRAND rates. (*Id.* at 9.) Second, TQ Delta correctly notes that CommScope failed to cite *any* authority supporting its proposition that when a jury awards less in royalty damages for

[8] CommScope notes that Aware's licenses were structured to [redacted], and argues that TQ Delta should have done the same. (Dkt. No. 541 at 7.)

infringement than a patentee's request, the infringer is entitled to JMOL on a claim for breach of FRAND. (*Id.*) It argues that determining damages for infringement of SEPs is distinct from assessing whether a license offer is FRAND. (*Id.*) TQ Delta also notes that FRAND rates are found in a range rather than a single rate, such that even if [redacted] is a FRAND rate, [redacted] might be in the FRAND rate range as well. (*Id.*, citing *Microsoft Corp. v. Motorola, Inc.*, 795 F.3d 1024, 1044-45 (9th Cir. 2015) (finding that, "in determining the RAND rate and range for each SEP portfolio," the district court did not err).)

Referring back to its assertion that CommScope mischaracterized the rates its other licensees paid, TQ Delta notes that CommScope's argument relies on the Jury's acceptance of CommScope's argument regarding those rates. (*Id.* at 9–10.) In other words, the Jury did not have to credit CommScope's argument regarding the effective rates of [redacted] being [redacted] respectively. TQ Delta also points out that CommScope's argument ignores licenses to other CPE makers—[redacted]—in which TQ Delta's standard rates were paid. (*Id.* at 10.) As to CommScope's argument about the award being consistent with the [redacted] agreement to the [redacted] chipsets in the accused products, TQ Delta urges there is no support for this assertion. (*Id.*) It notes that [redacted] infringing units results in a total of $11,184,668.60, not $11,125,000. (*Id.*, citing Dkt. No. 532 at 47:24-48:1; Dkt. No. 513 at 2.) TQ Delta also argues that [redacted] (a chipmaker in [redacted] with TQ Delta) and CommScope (a DSL CPE maker) were not similarly situated and would not have received the same rate. (*Id.*)[9] Lastly, TQ Delta contends it presented unrebutted evidence that the claimed inventions are not limited to the chipsets. (*Id.*, citing, *inter alia*, Dkt. No. 530 at 23:11- 24:24, 41:9-42:3, 116:24-118:18.)

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[9] Citing Dkt. No. 528 at 25:14-26:4, 62:16-63:23, 157:1-15; Dkt. No. 532 at 52:18-53:15, 56:14-20; Dkt. No. 526 at 188:7-25; Dkt. No. 533 at 128:23-129:20, 132:10- 134:20; Dkt. No. 530 at 202:16-203:13, 208:5-209:23.

TQ Delta also argues that CommScope mischaracterizes Dr. Putnam's testimony and the law. (*Id.* at 13.) TQ Delta points out that Dr. Putnam specifically testified to the following: he took TQ Delta's FRAND obligations into account in his opinion (Dkt. No. 532 at 9:11-13:25); he considered FRAND obligations when apportioning the value of TQ Delta's SEPs (*id.* at 25:15-26:22, 30:24-33:9), and the final royalty he arrived at was non-discriminatory and comparable to the [redacted] license royalty (*id.* at 48:24-52:12). (Dkt. No. 545 at 13.) TQ Delta acknowledges that Dr. Putnam testified that TQ Delta's patent infringement damages were not constrained by its FRAND obligations, but urges that he considered FRAND in his damages analysis. (*Id.*, citing Dkt. No. 541 at 6.) Additionally, TQ Delta argues that case law does not require Dr. Putnam's damages model to be constrained by TQ Delta's FRAND obligation, arguing that damages for patent infringement is an issue separate and apart from a FRAND obligation. (*Id.*, quoting *HTC Corp. v. Telefonaktiebolaget LM Ericsson*, 12 F. 4th 476, 486, n.3 (5th Cir. 2021) (internal citations omitted) ("The act of determining the value of a standard[]essential patent for purposes of calculating damages is distinct from assessing whether a particular offer made during unique licensing negotiations was fair and reasonable.").)[10]

Lastly, TQ Delta addresses CommScope's apportionment argument. It asserts that Dr. Putnam did determine the value of the asserted SEPs and compared that value to offered rates, testifying that the gains of DSL over the next best alternative down to TQ Delta's asserted SEPs and compared the result of that apportionment to the [redacted] license. (*Id.* at 14–15, citing Dkt. No. 532 at 9:11-52:12.) TQ Delta additionally outlined the contrary evidence it presented rebutting

[10] TQ Delta concludes that CommScope's quotation from *HTC Corp* that "a jury assessing patent infringement damages undertakes the same task of assessing whether an offered rate is FRAND" is taken out of context from the concurrence. (Dkt. No. 545 at 14, citing Dkt. No. 541 at 6.) It notes that statement was made in evaluating whether patent damages law should be used in a jury instruction for a breach of FRAND case. (*Id.*, citing *HTC Corp.*, 12 F.4th at 492.)

CommScope's critiques of TQ Delta's apportionment at trial. (*Id.* at 15.) For example, TQ Delta's managing director testified that CommScope never told TQ Delta its rates were too high in view of the price of a DSL modem. (*Id.*, citing Dkt. No. 528 at 162:16–24.) Additionally, TQ Delta explains that Dr. Putnam's damages model did apportion down to the value of TQ Delta's SEPs, excluding the value of other SEPs and features of the accused products not covered by the SEPs. (*Id.*, citing Dkt. No. 532 at 33:10–45:9, 106:7–19.)

The Court is persuaded that CommScope's argument premised on the Jury's damages award is unavailing. The Court declines to find that anything meaningful to the question of TQ Delta's alleged breach of FRAND can be taken from the Jury's lump sum damages award, where the Jury *expressly* found that there was no breach of FRAND.[11] To determine that the Jury must have found breach due to the amount it awarded TQ Delta for infringement, when the Jury also determined that there was no breach, flies in the face of logic. The first issue with CommScope's argument is the assumption that the Jury must have credited CommScope's theory that it was similarly situated to TQ Delta's other licensees, such that CommScope too should have received the same or similar adjustments. As the Court acknowledged above, the Jury was free to credit TQ Delta's argument and evidence to the contrary.

Further, TQ Delta put on evidence that its damages theory was consistent with FRAND terms, in that it was reasonable and nondiscriminatory. The Court agrees with TQ Delta that it was apparent from Dr. Putnam's testimony that he did consider FRAND in his damages analysis and that he compared his proposed damages figures to TQ Delta's [redacted] license to confirm they were

[11] In addition to the arguments laid out in this Order, TQ Delta contends that Jury's verdict actually implies a royalty rate that is *greater* than the one sought by TQ Delta when one takes into account that TQ Delta's [redacted] offer was for a 100-patent portfolio. (Dkt. No. 545 at 11–12.) It essentially argues that because the Jury's award was only for four patents, and the standard rate offer was for a 100-patent portfolio, the Jury's [redacted] award implies that the Jury found that rates at least as high as [redacted] per product for the entire portfolio would be FRAND. (*Id.* at 12.) However, because the Court does not accept the premise that the Jury's damages award supports a reversal of the Jury finding that there was no breach of FRAND under these circumstances, the Court does not address this argument.

non-discriminatory. (*See* Dkt. No. 532 at 9:11-13:25; 25:15-26:22, 30:24-33:9; 48:24-52:12.) Dr. Putnam did not testify that the damages TQ Delta sought at trial were inconsistent with FRAND; he testified that his damages model was not "constrained by the [F]RAND obligation." (*See* Dkt. No. 532 at 115:2–4, 116:1–3.) The Court is unpersuaded that Dr. Putnam's testimony constitutes overwhelming evidence of breach necessitating judgment as a matter of law. Moreover, the Jury was instructed to "take[] into account TQ Delta's FRAND obligations," that "[t]he FRAND commitment in this case does not require any specific licensing model to determine a FRAND royalty," and to "determine a FRAND royalty based on the totality of the circumstances." (Dkt. No. 534 at 66:4–67:23.) Dr. Putnam's damages model conformed to these instructions.

Lastly, the Court finds that Dr. Putnam put on testimony of the value of TQ Delta's asserted SEPs, compared that value to offered rates, and testified that he apportioned the gains of DSL over FTTP. (*See* Dkt. No. 532 at 9:11–52:12.) CommScope's arguments centered on Dr. Putnam's damages testimony fail, and TQ Delta's damages case does not mandate a finding of breach of FRAND.

IV. CONCLUSION

Since the Court does not grant judgment as a matter of law that TQ Delta breached its FRAND obligation, the request for a new trial on damages necessarily fails. Having considered the Motion, the Court finds that it should be and hereby is **DENIED**. The parties are directed to jointly prepare a redacted version of this Order for public viewing and to file the same on the Court's docket as an attachment to a Notice of Redaction within five (5) business days of this Order.

So ORDERED and SIGNED this 15th day of February, 2024.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

TQ DELTA, LLC, *Plaintiff*, v. COMMSCOPE HOLDING COMPANY, INC., COMMSCOPE INC., ARRIS INTERNATIONAL LIMITED, ARRIS GLOBAL LTD., ARRIS US HOLDINGS, INC., ARRIS SOLUTIONS, INC., and ARRIS ENTERPRISES, LLC, *Defendants*.	§ § § § § § § § § § § § §	CIVIL ACTION NO. 2:21-CV-00310-JRG [redacted]

MEMORANDUM OPINION AND ORDER

Before the Court is Plaintiff TQ Delta, LLC's ("TQ Delta") Renewed Motion for Judgment as a Matter of Law that Defendants' Accused Products Infringe Claim 14 of the '008 Patent (the "Motion"). (Dkt. No. 539.) Having considered the Motion and the related briefing, and for the reasons that follow, the Court finds that the Motion should be and hereby is **DENIED**.

I. BACKGROUND

On August 13, 2021, TQ Delta filed the above-captioned case against CommScope Holding Company, Inc., CommScope Inc., Arris International Limited, Arris Global Ltd., Arris US Holdings, Inc., Arris Solutions, Inc., and Arris Enterprises, LLC (collectively, "CommScope"), asserting infringement of thirteen patents. (*See* Dkt. No. 1.) CommScope answered the Complaint on October 22, 2021, asserting the defenses of invalidity and noninfringement. (*See* Dkt. No. 17.) By the time of trial, TQ Delta had narrowed its case, and trial commenced with TQ Delta asserting infringement of claim 36 of U.S. Patent No. 7,570,686 (the "'686 Patent"), claim 17 of U.S. Patent No. 7,453,881 (the "'881 Patent"), claim 5 of U.S. Patent No. 8,276,048 (the "'048 Patent"), claim 14 of U.S. Patent No. 8,090,008 (the "'008 Patent"), claim 10 of U.S. Patent No. 8,462,835 (the

"'835 Patent"), claim 18 of U.S. Patent No. 8,468,411 (the "'411 Patent"), and claim 10 of U.S. Patent No. 9,154,354 (the "'354 Patent") (collectively, the "Asserted Claims"). (Dkt. No. 495 at 1.) CommScope similarly narrowed its invalidity theories to target only claim 36 of the '686 Patent, claim 5 of the '048 Patent, claim 14 of the '008 Patent, and claim 10 of the '835 Patent. (Dkt. No. 497.) CommScope asserted that claim 36 of the '686 Patent and claim 5 of the '048 Patent were invalid as obvious, and that claim 14 of the '008 Patent and claim 10 of the '835 Patent were invalid as either anticipated or if not, obvious. (*Id.* at 2.) CommScope maintained that none of the Asserted Claims were infringed. (*See* Dkt. No. 466 at 4.)

On March 17, 2023, a jury trial commenced in this case. After the close of evidence on March 23, 2023, the Court took up matters from both sides under Federal Rule of Civil Procedure 50(a). In relevant part, TQ Delta moved the Court to enter judgment as a matter of law ("JMOL") that claim 14 of the '008 Patent was infringed, which CommScope opposed, arguing that the '008 Patent was standard essential. (Dkt. No. 533 at 205:12–23; 215:10–25.) The Court denied TQ Delta's 50(a) motion.

In response to the Court's request that the parties clarify which patents were and were not standard essential patents ("SEPs"), counsel for CommScope emailed the Court on March 22, 2023 and explained its belief that the '008 Patent was "neither essential nor infringed, but in the event that the jury finds [it] to be infringed, then the patent must, by definition, be essential and subject to TQ Delta's RAND commitment." (Dkt. No. 549-2 at 1.)

On the morning of March 24, 2023, the Court held a formal charge conference where it took up challenges to its jury instructions and verdict form. (*See* Dkt. No. 534.) In relevant part, the jury instructions included the following:

> In light of this FRAND commitment, ladies and gentlemen, I have referred at times in these instructions to SEPs, standard essential patents. The parties have stipulated that the '686

> Patent, the '881 Patent, the '008 Patent, and the '835 Patent, and the '354 Patent are standard essential patents or SEPs.

(Dkt. No. 534 at 66:23–67:3.) There were no objections to this instruction at the formal charge conference. (*See id.* at 13:15–18, 66:23–67:3.) That afternoon, the Jury returned its verdict. (*See* Dkt. No. 508.) In pertinent part, the Jury found that claim 14 of the '008 Patent was not infringed and not invalid.[1] (Dkt. No. 508 at 4–5.) On May 3, 3023, the Court entered final judgment on the verdict. (*See* Dkt. No. 513 at 2.)

TQ Delta now renews its 50(a) JMOL that CommScope infringed claim 14 of the '008 Patent, and in the alternative, seeks a new trial on the infringement of that claim.

II. LEGAL STANDARD

Upon a party's renewed motion for judgment as a matter of law following a jury verdict, the Court asks whether "the state of proof is such that reasonable and impartial minds could reach the conclusion the jury expressed in its verdict." FED. R. CIV. P. 50(b); *Am. Home Assur. Co. v. United Space Alliance*, 378 F.3d 482, 487 (5th Cir. 2004). "The grant or denial of a motion for judgment as a matter of law is a procedural issue not unique to patent law, reviewed under the law of the regional circuit in which the appeal from the district court would usually lie." *Finisar Corp. v. DirectTV Group, Inc.*, 523 F.3d 1323, 1332 (Fed. Cir. 2008). "A JMOL may only be granted when, 'viewing the evidence in the light most favorable to the verdict, the evidence points so strongly and overwhelmingly in favor of one party that the court believes that reasonable jurors could not arrive at any contrary conclusion.'" *Versata Software, Inc. v. SAP Am., Inc.*, 717 F.3d

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[1] The Jury found that CommScope infringed claim 17 of the '881 Patent, claim 36 of the '686 Patent, claim 5 of the '048 Patent, claim 10 of the '835 Patent, claim 18 of the '411 Patent, and claim 10 of the '354 Patent. (*Id.* at 4.) The Jury also found that CommScope's infringement was willful. (*Id.* at 6.) However, the Jury also determined that claim 36 of the '686 Patent and claim 10 of the '835 Patent were invalid. (*Id.* at 5.)

1255, 1261 (Fed. Cir. 2013) (quoting *Dresser-Rand Co. v. Virtual Automation, Inc.*, 361 F.3d 831, 838 (5th Cir. 2004)).

Under Fifth Circuit law, a court is to be "especially deferential" to a jury's verdict, and must not reverse the jury's findings unless they are not supported by substantial evidence. *Baisden v. I'm Ready Productions, Inc.*, 693 F.3d 491, 499 (5th Cir. 2012). "Substantial evidence is defined as evidence of such quality and weight that reasonable and fair-minded men in the exercise of impartial judgment might reach different conclusions." *Threlkeld v. Total Petroleum, Inc.*, 211 F.3d 887, 891 (5th Cir. 2000). A JMOL must be denied "unless the facts and inferences point so strongly and overwhelmingly in the movant's favor that reasonable jurors could not reach a contrary conclusion." *Baisden* 393 F.3d at 498 (citation omitted). However, "[t]here must be more than a mere scintilla of evidence in the record to prevent judgment as a matter of law in favor of the movant." *Arismendez v. Nightingale Home Health Care, Inc.*, 493 F.3d 602, 606 (5th Cir. 2007).

In evaluating a motion for judgment as a matter of law, a court must "draw all reasonable inferences in the light most favorable to the verdict and cannot substitute other inferences that [the court] might regard as more reasonable." *E.E.O.C. v. Boh Bros. Const. Co., L.L.C.*, 731 F.3d 444, 451 (5th Cir. 2013) (citation omitted). However, "[c]redibility determinations, the weighing of the evidence, and the drawing of legitimate inferences from the facts are jury functions, not those of a judge." *Reeves v. Sanderson Plumbing Prods., Inc.*, 530 U.S. 133, 150 (2000). "[T]he court should give credence to the evidence favoring the nonmovant as well as that 'evidence supporting the moving party that is uncontradicted and unimpeached, at least to the extent that evidence comes from disinterested witnesses.'" *Id.* at 151 (citation omitted).

Further, "courts do not grant new trials unless it is reasonably clear that prejudicial error has crept into the record or that substantial justice has not been done, and the burden of showing harmful error rests on the party seeking the new trial." *Metaswitch Networks Ltd. v. Genband US LLC*, 2017 U.S. Dist. LEXIS 137926, at *8 (E.D. Tex. Aug. 28, 2017). "A new trial may be granted, for example, if the district court finds the verdict is against the weight of the evidence, the damages awarded are excessive, the trial was unfair, or prejudicial error was committed in its course." *Smith v. Transworld Drilling Co.*, 773 F.2d 610, 612–13 (5th Cir. 1985); *see also Laxton v. Gap Inc.*, 333 F.3d 572, 586 (5th Cir. 2003).

III. DISCUSSION

TQ Delta moves for renewed JMOL pursuant to Federal Rule of Civil Procedure 50(b) that claim 14 of the '008 Patent was infringed. Infringement can be proven based on an accused product's use of an industry standard if the asserted claim is standard essential. *INVT SPE LLC v. Int'l Trade Comm'n*, 46 F.4th 1361, 1377 (Fed. Cir. 2022) (internal citations omitted). Claims are standard essential if the reach of the claims includes any device that practices the standard. *Id.* Only in the situation where a patent covers every possible implementation of a standard can infringement be shown by compliance with the standard. *Fujitsu Ltd. v. Netgear Inc.*, 620 F.3d 1321, 1328 (Fed. Cir. 2010). However, the "industry standard [may] not provide the level of specificity required to establish that practicing that standard would always result in infringement." *Id.*

At trial, TQ Delta theorized that claim 14 of the '008 Patent was essential to the standard known as VDSL2, that CommScope accused products implemented VDSL2, and thus that CommScope infringed claim 14 of the '008 Patent. (*See* Dkt. No. 539 at 3.) This Motion renews TQ Delta's motion for the same relief requested (and denied) at the Rule 50(a) stage. There, as

here, TQ Delta argued that its expert mapped all of the elements of claim 14 to portions of the VDSL2 standard, and demonstrated that all accused products complied with the standard, such that no reasonable juror could find that the accused products do not infringe claim 14. (Dkt. No. 533 at 205:12–23.)

A. No Stipulation of Standard Essentiality

As a threshold matter, TQ Delta asserts that CommScope stipulated that the ’008 Patent is standard essential to the VDSL2 standard by failing to object to the jury instruction “the ‘008 Patent … [is a] standard essential patent[] or SEP[],” and thereby conceded that there is no possible way to implement that standard without infringing claim 14. (Dkt. No. 539 at 1; Dkt. No. 534 at 66:25–67:3.) Although CommScope put on evidence and maintained that the ’008 Patent was not standard essential throughout trial and at the Rule 50(a) conference, TQ Delta argues that CommScope “did an about face” at the charge conference by stipulating that claim 14 was essential to the VDSL2 standard. (*Id.* at 4.) Under *Fujitsu*, TQ Delta argues, CommScope as “was free to either prove that the claims do not cover all implementations of the standard or to prove that it does not practice the standard.” (*Id.*, citing *Fujitsu*, 620 F.3d at 1327.) TQ Delta argues that CommScope ultimately stipulated to the opposite. (*Id.* at 7, citing Dkt. No. 530 at 66:25-67:2.)

In TQ Delta’s view, there was no fact question remaining regarding infringement of claim 14 of the ’008 Patent once CommScope “stipulated” to its standard essentiality in the jury instructions. (*Id.* at 4, 6, citing Dkt. No. 534 at 66:25–67:2.) It also places great emphasis on the fact that the Court instructed the Jury that “when the lawyers for both sides stipulate as to the existence of a fact, then you must, unless otherwise instructed, accept the stipulation as evidence and consider the fact as proven.” (*Id.*, citing Dkt. No. 534 at 25:17–21.) TQ Delta concludes that

in light of this, no reasonable jury could have found that the ’008 Patent was not standard essential to the VDSL2 standard. (*Id.*)

In response, CommScope clarifies that it never did an “about face” regarding infringement or the standard essentiality of the ’008 Patent. (Dkt. No. 549 at 8.) Throughout trial, CommScope argued that the accused products did not meet claim elements 14[b] and 14[c] of the ’008 patent because Section 12.3.6.2 and Table 12-70 of the VDSL2 standard did not work in the same way as claim 14. (*Id.* at 9.) It points to its communication to the Court, asserting that it always maintained that the ’008 patent was not infringed, but “*in the event* that the jury finds [the ’008 Patent] to be infringed, then the patent must, by definition, be essential and subject to TQ Delta’s RAND commitment.” (Dkt. No. 549 at 8, citing Dkt. No. 549-2.)

TQ Delta ultimately argues that CommScope stipulated to infringement,[2] and CommScope vehemently disagrees. It asserts this is supported by the jury instructions and verdict form, which unambiguously left infringement of the ’008 Patent for the Jury to decide.[3] (*Id.* at 9; Dkt. No. 563 at 2.) In CommScope’s view, TQ Delta ignores the context of the jury instruction stating that the parties stipulated to the standard essentiality of the ’008 Patent. (*Id.* at 10.) It urges that the Court’s instruction states that, *in the context of the FRAND commitment*, the parties agreed that if damages were incurred for the ’008 patent, those damages are limited by FRAND. (*Id.*, citing Dkt. No. 534 at 66:23-68:3.)

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[2] TQ Delta asserts “by stipulating that the 008 Patent is standard essential, CommScope conceded that claim elements 14[b] and 14[c] read on all compliant implementations of the VDSL2 standard” and that “[i]f CommScope believed that [TQ Delta] failed to prove that the 008 Patent is standard essential, CommScope should have sent that issue to the jury.” (Dkt. No. 556 at 1.)

[3] For support, CommScope points to its proposed jury instruction stating that “the Court is not instructing you that the asserted patents are actually essential to any standard.” (Dkt. 549 at 9, citing Dkt. No. 549-4 at 36.) TQ Delta argues that this is misdirection—that proposed instruction was a disputed instruction, and that CommScope did not maintain this position through the charge conference. (Dkt. 556 at 2.)

The Court agrees that the record supports CommScope's argument that it never stipulated to the standard essentiality of the '008 Patent for infringement purposes. Instead, as CommScope's email to the Court clarifies, standard essentiality was agreed to only in the event that the Jury found infringement for the purposes of FRAND damages. (*See* Dkt. No. 549-2 at 1 ("CommScope contends that U.S. Patent Nos. …8,090,008…[is] neither essential nor infringed, but in the event that the jury finds [infringement], then the patent must, by definition, be essential and subject to TQ Delta's RAND commitment.").) TQ Delta asserts that there is nothing in the instruction suggesting that CommScope was entitled to the upside of standard essentiality (the FRAND encumberment) while maintaining that the '008 Patent is not standard essential for infringement purposes. (Dkt. No. 556 at 2.) The Court disagrees.

The Court's instruction regarding the stipulation applies only in the patent damages context. First, when read in the context of the remainder of the jury instructions and the verdict form, the stipulation is plainly conditional—the Jury would only reach the question of patent damages, and thus the stipulation, if it first found infringement and validity. (*See* Dkt. No. 508 at 7.) Second, there were no objections to the instruction or the verdict form, which made clear that infringement was still an issue to be decided by the Jury. CommScope could properly contest standard essentiality and infringement, *and* conditionally stipulate to standard essentiality in the case that the Jury found infringement because TQ Delta's infringement theory depended on a finding of essentiality. TQ Delta's infringement theory at trial was that the '008 Patent was standard essential, and that CommScope accused products practiced the standard. Necessarily then, if the Jury found infringement, it must have found that the '008 Patent was standard essential.

Accordingly, CommScope's position was not an unfair taking of the "upside" of standard essentiality—rather, it was the logical result of TQ Delta's infringement theory. Since there was

no stipulation to standard essentiality for the purposes of infringement and the instruction to the Jury regarding the stipulation applied only in the patent damages context, the Court moves next to the parties' substantive arguments.

B. TQ Delta Failed to Meet Its Burden to Prove Infringement of the '008 Patent

i. Party Arguments Regarding Standard Essentiality

TQ Delta argues that, even if CommScope did not stipulate to standard essentiality, there is not legally sufficient evidence of record from which a reasonable jury could have found non-infringement of claim 14 of the '008 Patent. (Dkt. No. 539 at 7.) Claim 14 recites:

> 14[Pre] – A multi carrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:
>
> 14[a] – associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudorandom number generator;
>
> 14[b] – computing a phase shift for each carrier signal based on the value associated with that carrier signal; and
>
> 14[c] – combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

(Dkt. No. 1-4.) The Court construed the term "phase characteristic(s)" found in the preamble and element 14[c] as "one or more values that represent the language aspect of a constellation point." (Dkt. No. 169 at 63.) The Court further construed "computing a phase shift for each carrier signal" in element 14[b] to mean "computing the amount by which a phase is adjusted for each carrier signal." (*Id.* at 77.)

TQ Delta asserts that its expert, Dr. Madisetti, presented infringement evidence "in the form of the VDSL2 standard, data sheets, the [redacted], block diagrams, source code and source code specifications, testimony from the source code developer, Broadcom, and product testing and simulations" to conclude that each accused product infringed each element of claim 14. (Dkt. No.

539 at 8, citing Dkt. No. 530 at 115:1–25.) Conversely, CommScope argues that Dr. Madisetti failed to prove that claim elements 14[b] and 14[c] correspond with either the VDSL2 standard (specifically, Section 12.3.6.2 and Table 12-70 of the standard) or CommScope's accused products. (Dkt. No. 549 at 3.) Therefore, whether TQ Delta met its burden to prove that claim 14 was infringed depends on the evidence and testimony concerning claim elements 14[b] and 14[c].[4]

TQ Delta's infringement argument is grounded in the language of the preamble of claim 14. (*See* Dkt. No. 539 at 11.) It argues that the only carrier signals for which a phase shift must be computed and for which the phase shift is combined with the phase characteristic are the "plurality of carrier signals for modulating a bit stream" recited in the preamble. (*Id.*) At trial, TQ Delta mapped the claimed "plurality of carrier signals" to the subcarriers identified in Table 12-68, reproduced below, of the VDSL2 Standard (*see* Dkt. No. 530 at 120:17–22):

Table 12-68 –Bit mapping for R-P-MEDLEY with two bytes per DMT symbol

Subcarrier index	Constellation point
5, 10, 15, ..., 5 n, ...	00
1, 11, 21, ..., 10 n + 1, ...	SOC message bits 0 and 1
2, 12, 22, ..., 10 n + 2, ...	SOC message bits 2 and 3
3, 13, 23, ..., 10 n + 3, ...	SOC message bits 4 and 5
4, 14, 24, ..., 10 n + 4, ...	SOC message bits 6 and 7
6, 16, 26, ..., 10 n + 6, ...	SOC message bits 8 and 9
7, 17, 27, ..., 10 n + 7, ...	SOC message bits 10 and 11
8, 18, 28, ..., 10 n + 8, ...	SOC message bits 12 and 13
9, 19, 29, ..., 10 n + 9, ...	SOC message bits 14 and 15
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10n+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

[4] TQ Delta's Motion argues that it established that claim elements 14[Pre] and 14[a] practiced the VDSL2 standard as well. (*See* Dkt. No. 539 at 9–10.) As CommScope's Opposition addresses only elements 14[b] and 14[c], this Order analyzes only those elements. (*See* Dkt. No. 549.)

(Trial Ex. 34 at 261.) Dr. Madisetti explained that the claimed "phase characteristic" for each individual carrier signal is the constellation point values corresponding to the special operations channel ("SOC") message 0 and 1, 2 and 3, 4, and 5, etc. (Dkt. No. 530 at 121:7–21.) TQ Delta argues that the claimed "plurality of carrier signals for modulating a bit stream wherein each carrier signal has a phase characteristic associated with the bit stream" are only those subcarriers that the transceiver "uses…for modulating the bit stream" of the SOC messages. (Dkt. No. 539 at 9–10.)

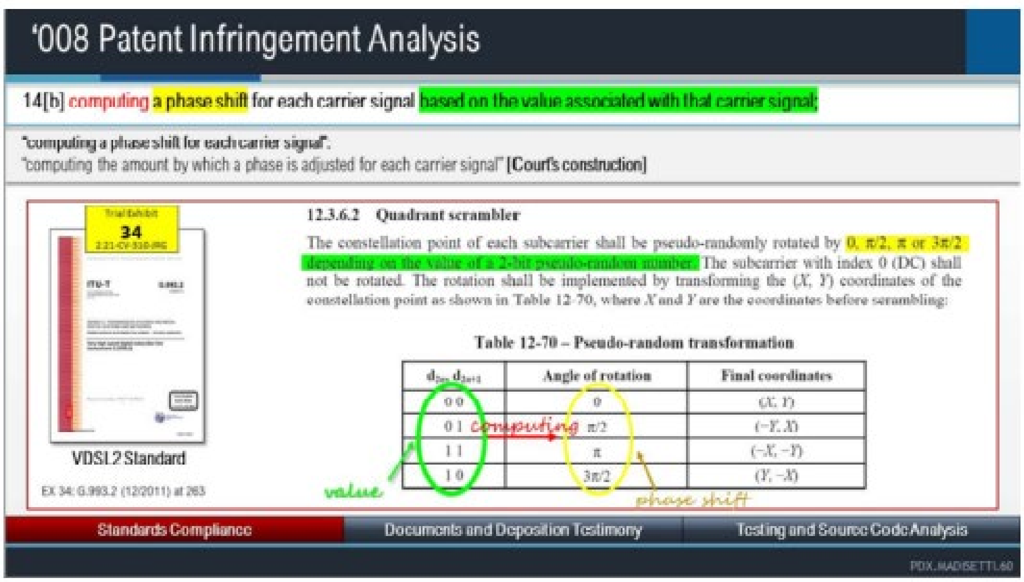
TQ Delta urges that another signal, called subcarrier zero, is not one of the "plurality of carrier signals for modulating a bit stream" and is not included in the first column of Table 12-68. (*Id.* at 10.) In TQ Delta's view, since subcarrier zero does not "ha[ve] a phase characteristic associated with the bit stream" it cannot be one of the "plurality of carrier signals." (*Id.*) Further, TQ Delta argues that subcarrier zero is not modulated at all and does not have a phase characteristic because it carriers a direct current. (*Id.*, citing Trial Ex. 34 at TQD_TX00153996.) Essentially, TQ Delta argues that subcarrier zero falls outside of the scope of claim 14.

On cross, Dr. Madisetti admitted that subcarrier zero was not combined or rotated by a phase shift.[5] However, TQ Delta maintains that this admission is of no import because subcarrier zero is not one of the "plurality of carrier signals" which must be combined or rotated. (*Id.* at 12.) TQ Delta additionally notes that Dr. Madisetti "confirmed the irrelevance of [subcarrier zero] to his infringement opinions." (*Id.* at 12–13, citing Dkt. No. 530 at 168:8–20 (Dr. Madisetti stating on redirect examination that he did not "rely" on subcarrier zero).) TQ Delta argues that the entire basis for CommScope's non-infringement argument at trial and in the briefing is that "when [the subcarrier index] is set to 0, there is no rotation." (*Id.* at 13, quoting Dkt. No. 533 at 215:15–16.)

[5] "Q. Now, Doctor Madisetti, just check me and make sure I'm reading right. Does it state, quote, the subcarrier with index 0 DC shall not be rotated? Did I read that correctly, sir? A. Yes. . . .Q. Okay. So what this tells us is that the subcarrier with index 0 shall not be rotated. Is that what it says, sir? A. Yes, that's what it says." (Dkt. No. 530 at 165:13-23.)

Therefore, TQ Delta concludes that there was no legally sufficient evidence for the jury to find that claim 14 did not read on the VDSL2 standard even though the subcarrier index 0 is not rotated. (*Id.*)

CommScope first responds that Dr. Madisetti failed to prove that the VDSL2 standard computed a phase shift for "each carrier signal" as required by claim element 14[b]. (Dkt. No. 549 at 3.) For this element, Dr. Madisetti relied on Table 12-70 of the standard, which says that each "constellation point" or "phase characteristic" (i.e., the "X, Y" pair) "of each subcarrier shall be pseudo-randomly rotated by ***0***, π/2, π, or 3 π/2 depending on the value of a 2-bit pseudo-random number":



(*Id.* at 4, quoting Tr. Ex. 34 at TQD_TX00153996) (emphasis added).

Dr. Madisetti testified that the "first column represents the value shown in green, and you are computing based on that value an angle of rotation which is 0[,] 90, 180, or 270, shown in yellow." (*Id.*, quoting Dkt. No. 530 at 126:3–15.) Section 12.3.6.2 states that "coordinates of the constellation point as shown in Table 12-70, where X and Y are the coordinates before

scrambling." (*Id.*, quoting Tr. Ex. 34 at TQD_TX00153996.) CommScope argues this means that the first row displaying a final coordinate of "X, Y" has no "phase shift" computed. (*Id.*) According to CommScope, element 14[b] requires more than adding a zero angle of rotation and having "the exact same value"; rather, there must be an *adjustment* in the final coordinates (the phase characteristics). (*Id.* at 4–5.)

Next, CommScope argues that TQ Delta failed to show that the phase shift computed for each respective carrier signal was combined with the phase characteristic of that carrier signal as required by claim element 14[c]. (*Id.* at 6.) It points to the portion of Dr. Madisetti's testimony where he admitted that the subcarrier zero shall not be rotated and concludes that "therefore Section 12.3.6.2 fails to combine the phase shift computed for each respective carrier signal." (*Id.* at 7, citing Dkt. No. 530 at 165:13-23.) It reiterates that "Table 12-70 does not combine the phase shift computed for the carrier having the bit value of 0, 0 with the phase characteristic for that bit value because the original coordinate (X, Y) is the same as the final coordinate (X, Y)." (*Id.*) Moreover, it points out that TQ Delta never testified that the carrier having the bit value of 0, 0 was excluded from the plurality of carriers. (*Id.*)

Regarding claim element 14[b], TQ Delta responds that CommScope's argument that a zero degree phase shift would not qualify as an "amount by which a phase is adjusted" contradicts the plain meaning of "amount," as no reasonable juror could conclude that zero is not an amount. (Dkt. No. 556 at 3.) It further points out that the second column of Table 12-70 of the standard (*see supra*) lists a zero phase shift as "an angle of rotation." (*Id.*, citing Dkt. No. 530 at 126:5–15.) TQ Delta asserts that Dr. Madisetti identified that 0 degree phase shift as one of the phase shift amounts by which a carrier signal is adjusted. (*Id.*, citing Dkt. No. 530 at 126:5–15.) It concludes

that element 14[b] is met, including when one of the possible computed phase shift amounts is zero. (*Id.*)

With respect to claim element 14[c], TQ Delta argues that CommScope's argument contradicts the VDSL2 standard. (*Id.* at 5.) It notes that "[c]ontrary to CommScope's assertion, the VDSL2 standard requires adjusting the phase characteristic by the 'amount of rotation' listed in column 2 of Table 12-70, i.e., combining the computed phase shift with the phase characteristic, including when the bit value is (0,0)." (*Id.*) For that reason, it argues that CommScope's contention that Table 12-70 does not combine the phase shift computed for the carrier with the bit value of 0, 0 with the phase characteristic for that bit value does not comport with the standard. (*Id.*) TQ Delta additionally disputes CommScope's argument that TQ Delta never testified that the carrier having the bit value of 0, 0 was excluded from the plurality of carriers. (*Id.* at 5.) It asserts that Dr. Madisetti testified that the carrier signals identified in Table 12-68 are the claimed "plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream," and that subcarrier zero is not one of them. (*Id.*, citing Dkt. No. 530 at 118:19-119:3, 119:23-120:7, 120:14-121:21, and 168:8-20.)

CommScope contends that TQ Delta's argument for claim 14 "hinges on its assertion that the plain meaning of 'amount' is so clear that 'no reasonable juror could conclude that zero is not an amount.'" (Dkt. No. 563 at 3.) It urges that whether zero is an amount is a "quintessential question of fact" that the Jury could, and properly did, answer in the negative. (*Id.*) Regarding element 14[b], it argues that the evidence demonstrated that a phase shift of zero is not an "amount by which a phase shift is adjusted," as required by the Court's construction of claim element 14[b]. (*Id.*) It notes that Section 12.3.6.2 unambiguously states that original "coordinates of the constellation point as shown in Table 12-70, where X and Y are the coordinates before

scrambling." (*Id.*, citing Tr. Ex. 34 at TQD_TX00153996.) In CommScope's view, this means that the first row, with a final coordinate of X, Y, has no phase shift computed (or "adjusted")—the zero angle of rotation does not adjust the phase shift because the original X, Y coordinate remains the same. (*Id.* at 3–4.)

CommScope asserts that claim element 14[b] is also not met because the zero angle of rotation is not computed for "each carrier signal" as explained above, and "each carrier signal" is not combined because there is no phase shift for bit value 0, 0. (*Id.* at 4.) It additionally points out that TQ Delta never stated that the subcarrier zero is not one of the plurality of carrier signals; TQ Delta only stated that his infringement theory did not rely on that subcarrier. (*Id.*, citing Dkt. No. 530 at 168:12-16.)

ii. Court Analysis

As a preliminary matter, the Court clarifies the proper inquiry. The Fifth Circuit has held that a judgment as a matter of law should be granted only "[i]f the evidence at trial points so strongly and overwhelmingly in the movant's favor that reasonable jurors could not reach a contrary conclusion." *Omnitech Int'l, Inc. v. Clorox Co.*, 11 F3d 1316, 1323 (5th Cir. 1994) (citations omitted). However, "when the party moving for a directed verdict has such a burden, the evidence to support the granting of the motion must be so one-sided as to be of over-whelming effect." *Grey v. First Nat'l Bank in Dall.*, 393 F.2d 371, 380 (5th Cir. 1968). *See also*, *Core Wireless Licensing S.A.R.L. v. LG Elecs., Inc.*, 880 F.3d 1356, 1364 (Fed. Cir. 2018) (citing *Grey*, 393 F.2d at 380). Since the Jury has found that TQ Delta failed to carry its burden on infringement, TQ Delta must now show that the evidence that supports granting the Motion is "so one-sided as to be of overwhelming effect." *Grey*, 393 F.2d at 380. TQ Delta has not done so.

TQ Delta has failed to point to evidence of overwhelming effect showing that the Jury must have found infringement. Mere evidence does not amount to overwhelming evidence. One expert who testifies and is cross-examined does not overwhelm, especially where the cross-examination is done skillfully. Thus, after a fulsome review of the record, the Court finds that this issue is not "so one-sided" as to justify overturning the Jury's verdict. *Grey*, 393 F.2d at 380. The evidence is simply not so overwhelming that it required the Jury to find standard essentiality of claim 14 of the '008 Patent. Since TQ Delta's only infringement theory for the '008 Patent relied on establishing its standard essentiality, the Court need not reach the issue of whether the accused products practiced the standard.

C. A New Trial Is Not Warranted

In the alternative, TQ Delta argues that the Court should grant a new trial on the issue of the infringement of the '008 Patent. (Dkt. No. 539 at 14.) TQ Delta contends that the Jury was instructed that the parties stipulated to the standard essentiality of the '008 Patent, then turned around and argued to the jury that the VDSL Standard was different from claim 14. (*Id.*, citing 3/24/23 Tr. at 107:17–19.) In TQ Delta's view, this made the non-infringement verdict "against the weight of the evidence, based on unfair and irrelevant argument, and plainly unjust." (*Id.* at 15.) CommScope responds that the Jury had a legally sufficient evidentiary basis to find that the accused products do not infringe claim elements 14[b] and 14[c] of the '008 Patent. (Dkt. No. 549 at 11.) As a result, CommScope argues the Motion for New Trial should be denied. (*Id.* at 11–12.)

The Court agrees with CommScope—as discussed above, the Jury had legally sufficient evidence to conclude that the accused products did not infringe claim 14 of the '008 Patent. The Court further notes that TQ Delta failed to object to the "unfair and irrelevant" closing argument that it now cites to. (*See* Dkt. No. 534 at 107:1–25.)

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IV. CONCLUSION

Having considered the Motion, the Court finds that it should be and hereby is **DENIED.** The parties are directed to jointly prepare a redacted version of this Order for public viewing and to file the same on the Court's docket as an attachment to a Notice of Redaction within five (5) business days of this Order.

So ORDERED and SIGNED this 15th day of February, 2024.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

US007453881B2

(12) **United States Patent**
Tzannes et al.

(10) **Patent No.: US 7,453,881 B2**
(45) **Date of Patent: Nov. 18, 2008**

(54) **SYSTEMS AND METHODS FOR MULTI-PAIR ATM OVER DSL**

(75) Inventors: **Marcos C Tzannes**, Orinda, CA (US); **Edmund Reiter**, Lincoln, MA (US); **Christopher Cahill**, Northboro, MA (US)

(73) Assignee: **Aware, Inc.**, Bedford, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1024 days.

(21) Appl. No.: **10/264,258**

(22) Filed: **Oct. 4, 2002**

(65) **Prior Publication Data**

US 2003/0091053 A1 May 15, 2003

Related U.S. Application Data

(60) Provisional application No. 60/327,440, filed on Oct. 5, 2001.

(51) **Int. Cl.**
H04L 12/28 (2006.01)

(52) **U.S. Cl.** **370/395.1**; 370/535; 370/465

(58) **Field of Classification Search** .... None
See application file for complete search history.

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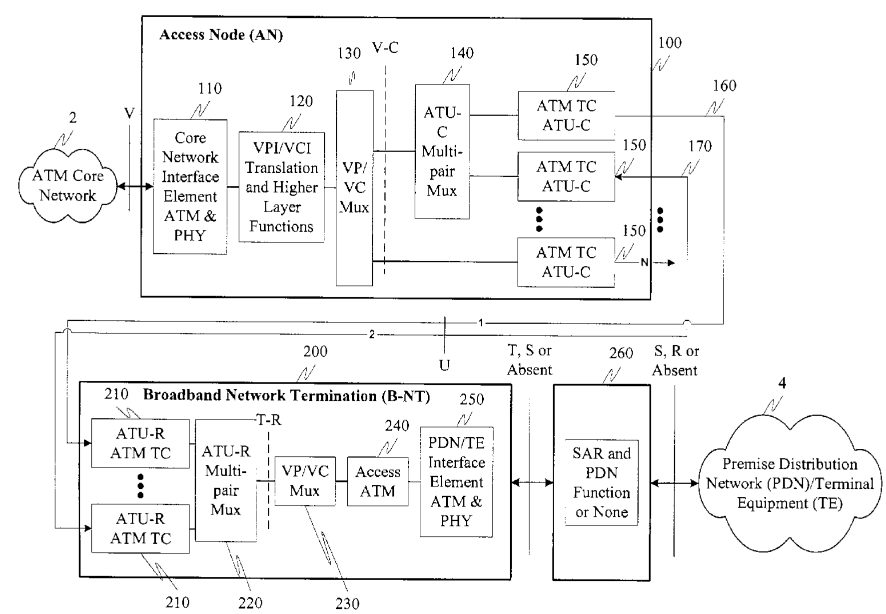
* cited by examiner

Primary Examiner—Duc C Ho
(74) *Attorney, Agent, or Firm*—Sheridan Ross P.C.; Jason H. Vick

(57) **ABSTRACT**

At a transmitter, an ATM cell stream is received from the ATM layer and is distributed on a cell-by-cell bases across multiple DSL PHY's. At the receiver, the cells from each DSL PHY are re-combined in the appropriate order to recreate the original ATM cell stream, which is then passed to the ATM layer.

42 Claims, 7 Drawing Sheets



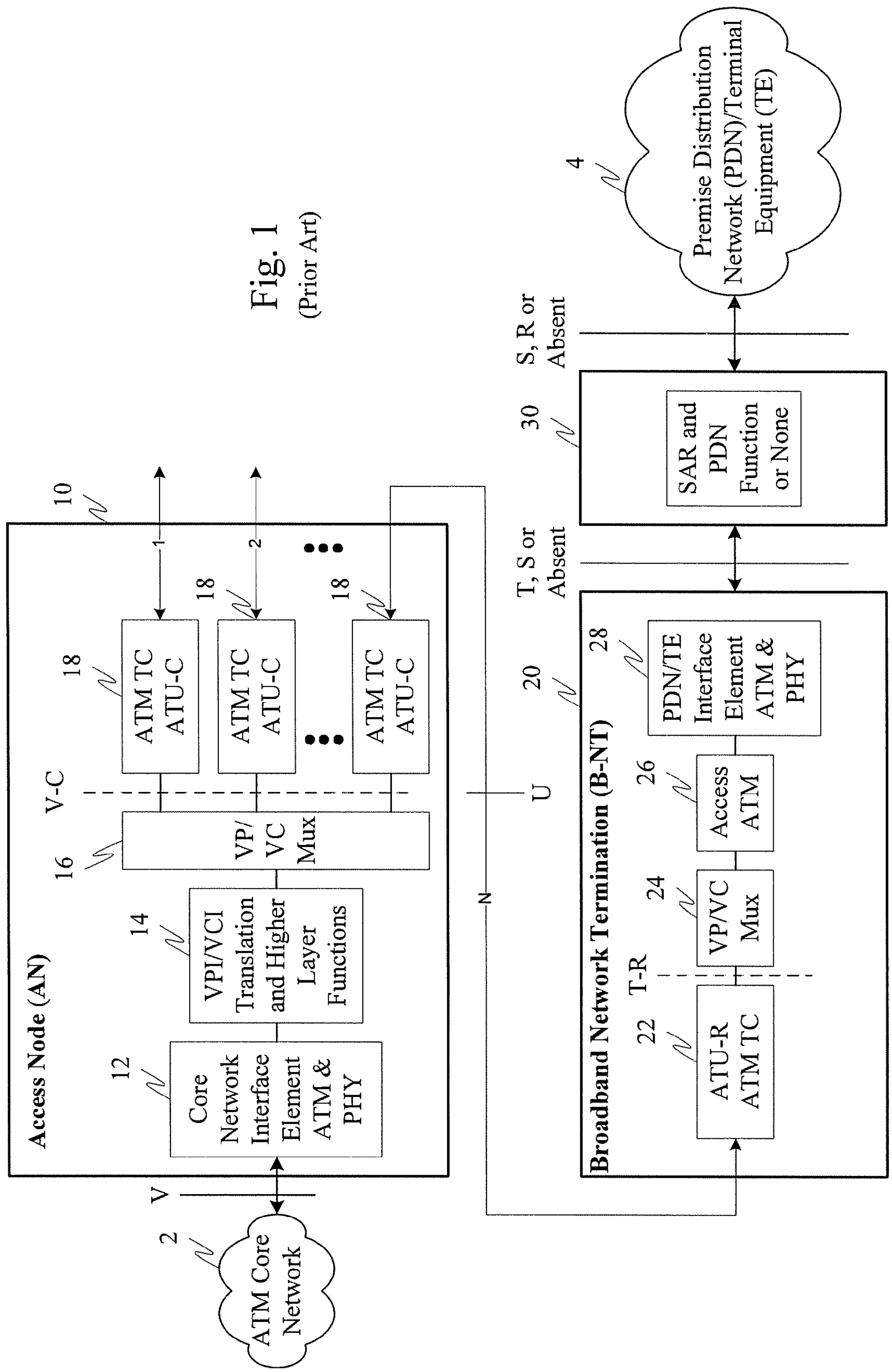


Fig. 1
(Prior Art)

TQD_TX-00043943

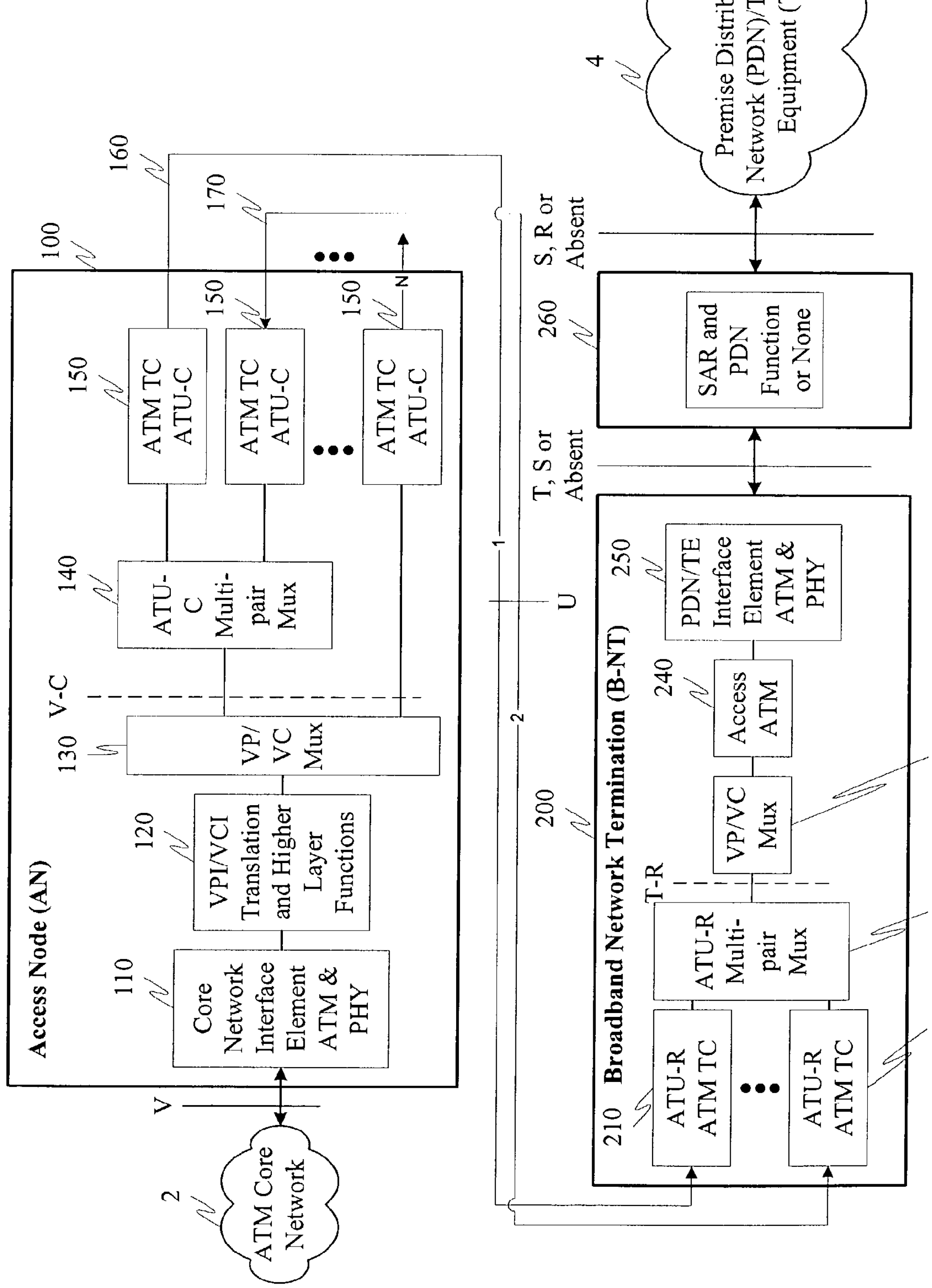


Fig. 2

TQD_TX-00043944

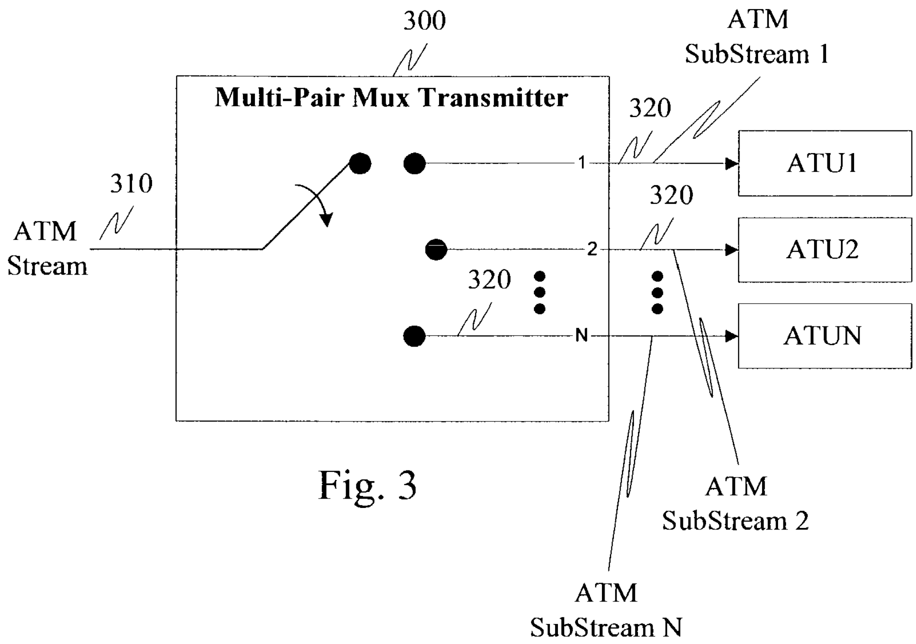


Fig. 3

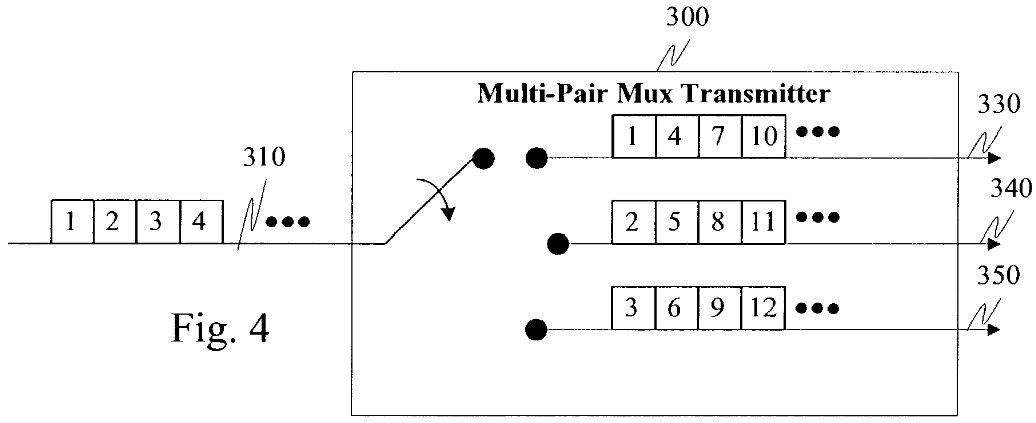


Fig. 4

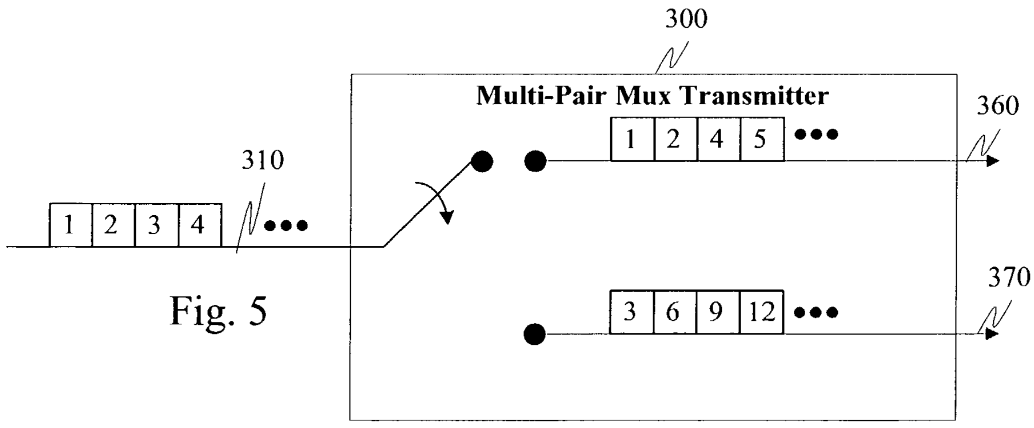


Fig. 5

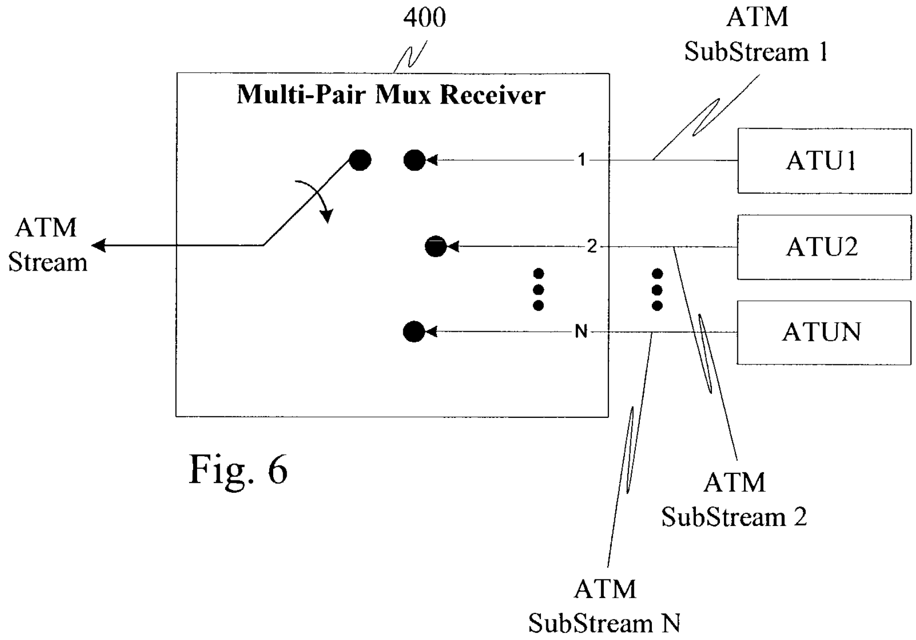


Fig. 6

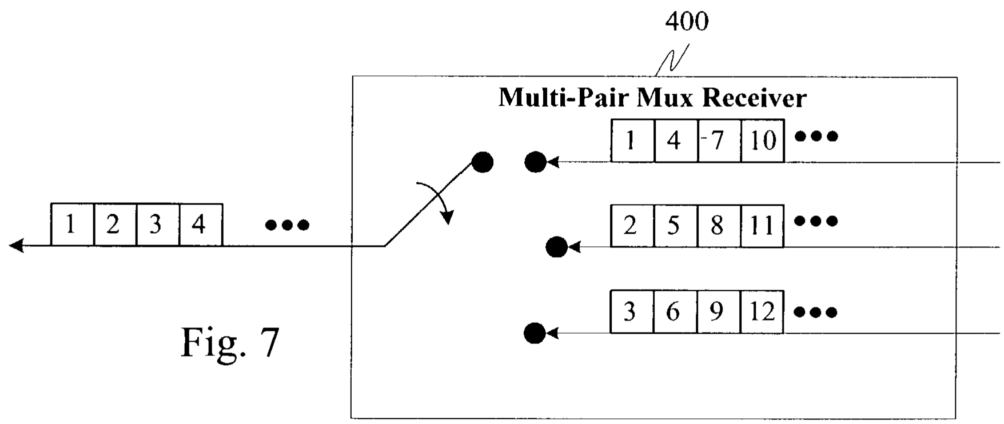


Fig. 7

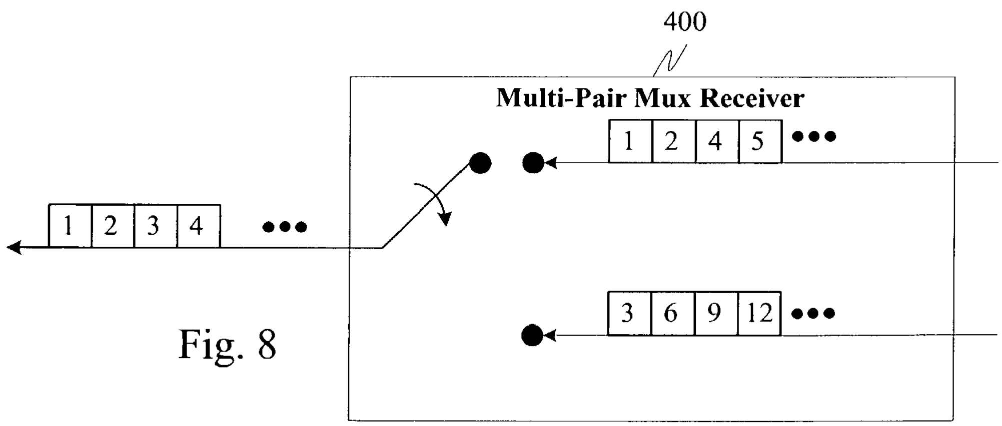


Fig. 8

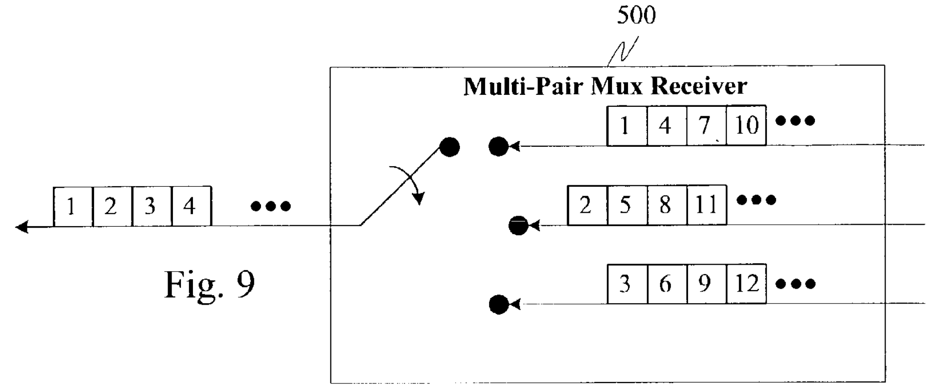


Fig. 9

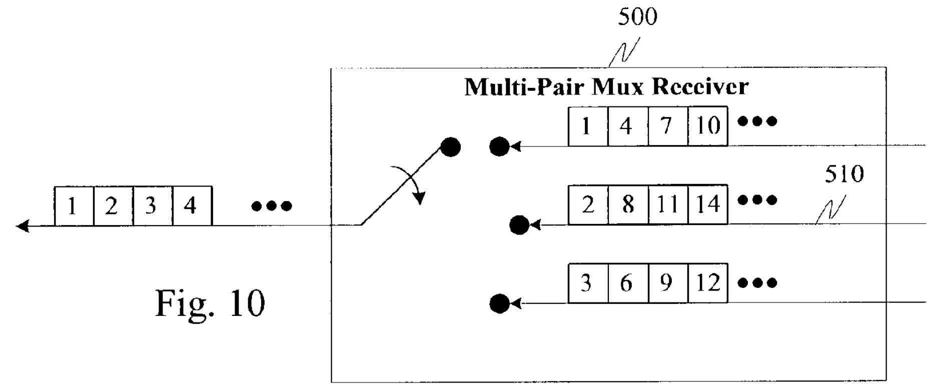


Fig. 10

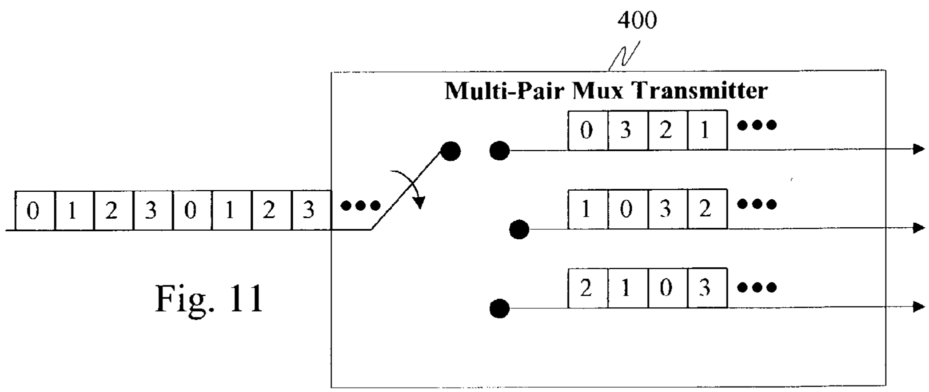


Fig. 11

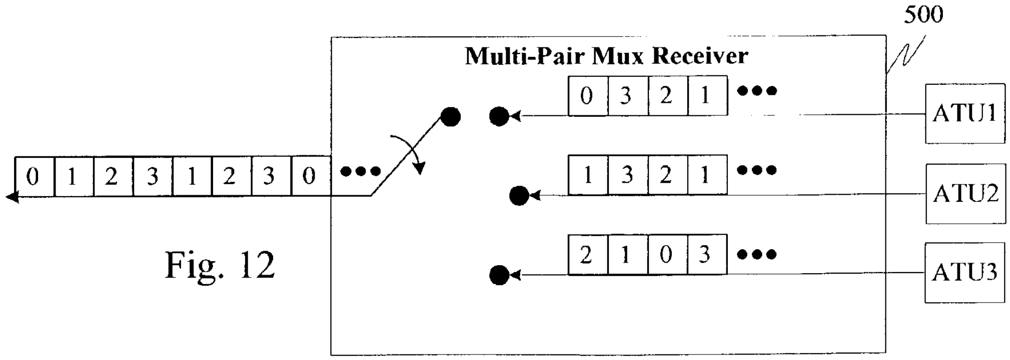


Fig. 12

<table>
<tr><th>Bit</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td>Byte 1</td><td colspan="4">Flow Control (GFC)</td><td colspan="4">VPI Value</td></tr>
<tr><td>Byte 2</td><td colspan="4">VPI Value</td><td colspan="4">VCI Value</td></tr>
<tr><td>Byte 3</td><td colspan="8">VCI Value</td></tr>
<tr><td>Byte 4</td><td colspan="4">VCI Value</td><td colspan="3">Payload Type</td><td></td></tr>
<tr><td>Byte 5</td><td colspan="8">HEC</td></tr>
</table>

Fig. 13

<table>
<tr><th>Bit</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td>Byte 1</td><td colspan="4">Flow Control (GFC)</td><td colspan="2">TIV</td><td colspan="2">MP Cntr</td></tr>
<tr><td>Byte 2</td><td colspan="6">MP Counter</td><td colspan="2">Reserved</td></tr>
<tr><td>Byte 3</td><td colspan="8">Reserved</td></tr>
<tr><td>Byte 4</td><td colspan="4">Reserved</td><td colspan="3">Payload Type</td><td>CLP</td></tr>
<tr><td>Byte 5</td><td colspan="8">HEC</td></tr>
</table>

Fig. 14

TQD_TX-00043948

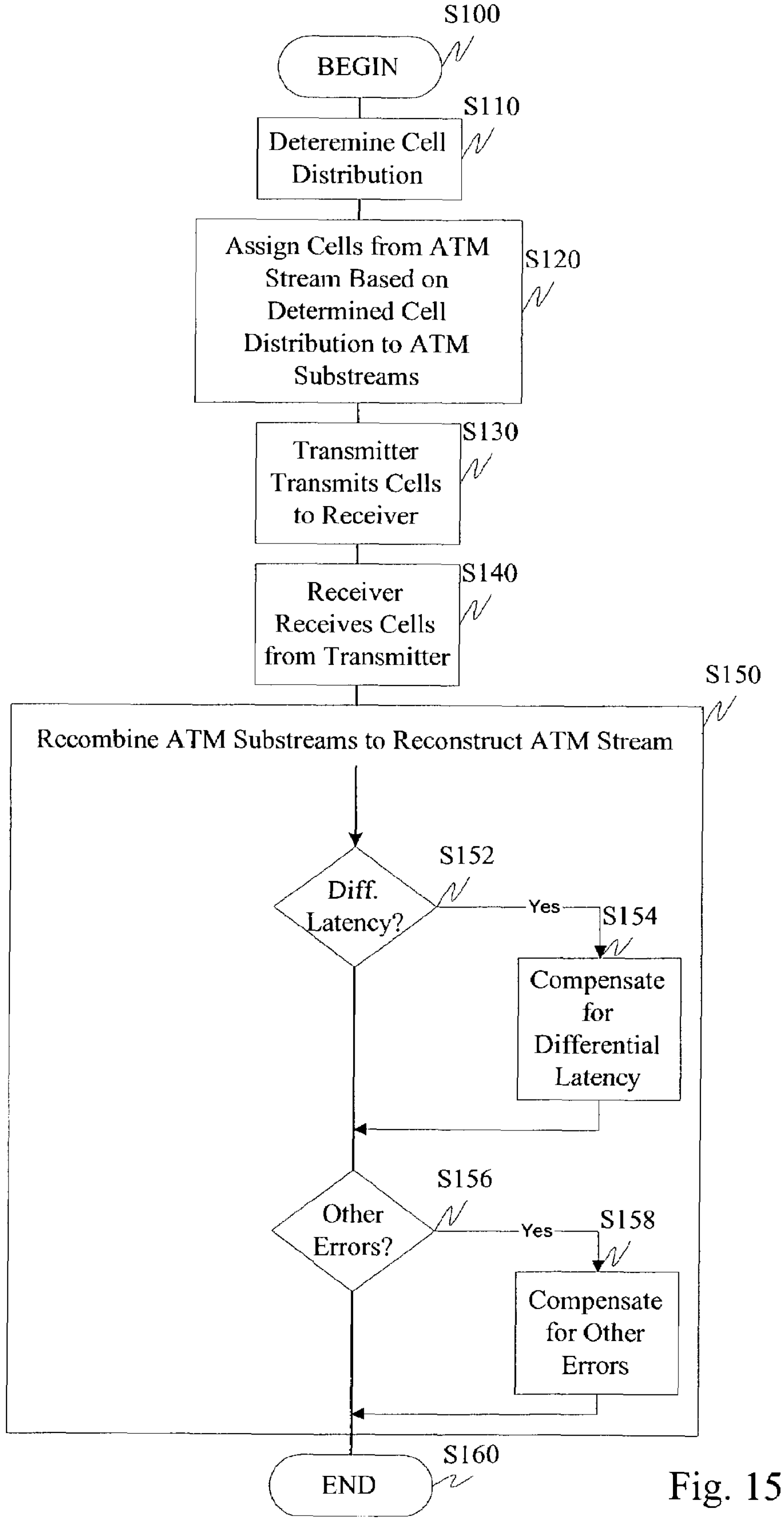

S100
BEGIN
S110
Deteremine Cell Distribution
Assign Cells from ATM Stream Based on Determined Cell Distribution to ATM Substreams
S120
S130
Transmitter Transmits Cells to Receiver
S140
Receiver Receives Cells from Transmitter
S150
Recombine ATM Substreams to Reconstruct ATM Stream
S152
Diff. Latency?
Yes
S154
Compensate for Differential Latency
S156
Other Errors?
Yes
S158
Compensate for Other Errors
S160
END

Fig. 15

SYSTEMS AND METHODS FOR MULTI-PAIR ATM OVER DSL

RELATED APPLICATION DATA

This application claims the benefit of and priority under 35 U.S.C. §119(e) to U.S. Patent Application Serial No. 60/327,440, filed Oct. 5, 2001, entitled "Multi-Pair ATM Over DSL," which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The systems and methods of this invention generally relate to communication systems. In particular, the systems and methods of this invention relate to asynchronous transfer mode (ATM) over digital subscriber line (DSL).

2. Description of Related Art

FIG. **1** illustrates the conventional configuration of a system for transporting ATM over DSL using a single latency ADSL configuration. As of the time of filing, single latency is most common form of ADSL deployment. Further details of this specific architecture can be found in DSL Forum Recommendation TR-042, incorporated herein by reference in its entirety.

For the system illustrated in FIG. **1**, the access node **10** serves as an ATM layer multiplexer/concentrator between the ATM core network **2** and the access network. As described in the above referenced DSL Forum Recommendation, for ATM systems, the channelization of different payloads is embedded within the ATM data stream using different virtual paths (VP) and/or virtual channels (VC). In the downstream direction, the VP/VC Mux module **16** and VPI/VCI translation module **14** receive cells from the core network interface element **12** and function to perform cell routing based on a virtual path identifier (VPI) and/or virtual channel identifier (VCI) to the appropriate ATU-C **18**. In the upstream direction, the VP/VC Mux module **16** and the VPI/VCI translation module **14** function to combine the cell streams from the ATU-C's **18** into a single ATM cell stream to the core ATM network **2**.

The broadband network termination (B-NT) **20** performs the functions of terminating the ADSL signal entering the user's premises via the twisted pair cable and the ATU-R **22** and provides either the T, S or R interface towards the premises distribution network/terminal equipment **4**. The access ATM module **26** and the VP/VC Mux module **24** perform the ATM layer functions to support the TC layers in the ATU-R. The broadband network termination **100** may also contain VPI/VCI translation functions to support multiplex/demultiplex of VC's between the ATU-R **22** and the premise distribution network/terminal equipment **4** on a VPI and/or VCI bases. The broadband network termination **20** may also comprise a PDN/TE interface element **28** and SAR module **30** the functions of which are well known and will be omitted for sake of clarity.

SUMMARY OF THE INVENTION

The exemplary systems and methods of this invention combine multiple DSL PHY's, i.e., multiple twisted wire pairs, to, for example, generate a high data rate connection for the transport of an ATM cell stream between the service provider and, for example, a DSL subscriber. The ATM cell stream may contain one or more payloads where each payload is channelized within the ATM data stream using different virtual paths (VP) and/or virtual channels (VC). At a transmitter, the ATM cell stream received from the ATM layer is distributed on a cell-by-cell bases across the multiple DSL PHY's. At the receiver, the cells from each DSL PHY are recombined in the appropriate order to recreate the original ATM cell stream, which is then passed to the ATM layer.

Accordingly, aspects of the invention relate to ATM communications.

Additional aspects of the invention relate to transporting ATM over DSL, and more particularly over ADSL.

Additional aspects of the invention also relate to distributing ATM cells from a single ATM cell stream across multiple twisted wire pairs.

Further aspects of the invention relate to distributing ATM cells from a single ATM cell stream across multiple DSL communication links.

Further aspects of the invention relate to varying data rates over the multiple twisted wire pairs over which distributed ATM cells are transported.

These and other features and advantages of this invention are described in, or apparent from, the following detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the invention will be described in detailed, with reference to the following figures, wherein:

FIG. **1** is a functional block diagram illustrating a conventional ATM over ADSL system;

FIG. **2** is a functional block diagram illustrating an exemplary system for transporting ATM over ADSL according to this invention;

FIG. **3** illustrates an exemplary functional block diagram of the multi-pair multiplexing transmitter according to this invention;

FIG. **4** illustrates a functional block diagram of a second exemplary multi-pair multiplexing transmitter according to this invention;

FIG. **5** illustrates a functional block diagram of a third exemplary embodiment of the multi-pair multiplexing transmitter according to this invention;

FIG. **6** illustrates a functional block diagram of an exemplary multi-pair multiplexing receiver according to this invention;

FIG. **7** illustrates a functional block diagram of a second exemplary multi-pair multiplexing receiver according to this invention;

FIG. **8** illustrates a functional block diagram of a third exemplary multi-pair multiplexing receiver according to this invention;

FIG. **9** is a functional block diagram illustrating a fourth exemplary multi-pair multiplexing receiver according to this invention;

FIG. **10** illustrates a functional block diagram of a fifth exemplary multi-pair multiplexing receiver according to this invention;

FIG. **11** illustrates a functional block diagram of a fourth exemplary multi-pair multiplexing transmitter according to this invention;

FIG. **12** is a functional block diagram illustrating a sixth exemplary multi-pair multiplexing receiver according to this invention;

FIG. **13** illustrates a standard five byte ATM UNI header;

FIG. **14** illustrates an exemplary modified ATM header according to this invention; and

FIG. **15** is a flowchart outlining an exemplary embodiment of a method for combining multiple DSL PHYs to transport an ATM cell stream between a service provider and a subscriber.

DETAILED DESCRIPTION OF THE INVENTION

The exemplary systems and the methods of this invention will be described in relation to digital subscriber line communications and more particularly to asymmetric digital subscriber line communications. However, to avoid unnecessarily obscuring the present invention, the following description omits well-known structures and devices that may be shown in block diagram form or otherwise summarized. For the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It should be appreciated however that the present invention may be practiced in variety of ways beyond the specific details set forth herein. For example, the systems and methods of this invention can generally be applied to any type of communications system including wireless communication systems, such as wireless LANs, power line communications, or any other systems or combination systems that use ATM.

Furthermore, while the exemplary embodiments illustrated herein show the various components of the communication system collocated, it is to be appreciated that the various components of the system can be located at distant portions of distributed network, such as a telecommunications network and/or the Internet, or within a dedicated ATM over DSL system. Thus, it should be appreciated that the components of the communication system can be combined into one or more devices or collocated on a particular node of a distributed network, such as a telecommunications network. It will be appreciated from the following description, and for reasons of computational efficiency, that the components of the communication system can be arranged at any location within a distributed network without affecting the operation of the system.

Furthermore, it should be appreciated that the various links connecting the elements can be wired or wireless links, or a combination thereof or any other know or later developed element(s) that is capable of supplying and/or communicating data to and from the connected elements. Additionally, the term module as used herein can refer to any know or later developed hardware, software, or combination of hardware and software that is capable of performing the functionality associated with that element.

Additionally, although this invention will be described in relation to ATM systems, the systems and methods of this invention can be applied to any transport protocol that uses cells or packets for transmitting information. Therefore, for example, the same methods can be used for the bonding of PHYs that transport Ethernet or IP packets. Furthermore, although this invention will be described in relation to ATM transported over DSL PHYs, other PHYs, such as cable, voice band modems, ATM-25, and the like, can also be used.

FIG. **2** illustrates an exemplary multi-pair ATM over DSL system. In particular, the system comprises an access node **100**, a broadband network termination **200**, an ATM core network **2** and premise distribution network/terminal equipment **4**. The access node **100** further comprises a core network interface element **110**, a VPI/VCI translation module **120**, a VP/VC Mux module **130**, an ATU-C multi-pair multiplexer **140** and a plurality of ATM TC ATU-C modules **150**. The broadband network termination **200** further comprises a plurality of ATU-R ATM TCs **210**, an ATU-R multi-pair multi-

plexer **220**, a VP/VC Mux module **230**, an access ATM module **240**, and a PDN/TE interface module **250**. Furthermore, the system comprises a SAR and PDN function module **260**, wherein the functions of like components have been discussed in relation to FIG. **1**.

The exemplary system illustrated in FIG. **2** distributes ATM cells from a single ATM cell stream across multiple ADSL PHY links, i.e., multiple twisted wire pairs (1 to n). The ATM cell stream, also referred to as the ATM stream, may comprise one or more payloads where each payload is channelized within the ATM stream using different virtual paths (VP) and/or virtual channels (VC). This can effectively create, for example, a high data rate ATM connection between a service provider and an ADSL subscriber.

In accordance with an exemplary embodiment of this invention, the ATU-C multi-pair multiplexer **140** is inserted between the VP/VC multiplexer **130** and the ATU-C's **150** at the V-C interface in the access node **100**. Additionally, the ATU-R multi-pair multiplexer **220** is added to the broadband network termination **200** at the T-R interface. Both of these multi-pair multiplexers have transmitter and receiver sections (not shown) whose operations are comparable. The multi-pair multiplexer transmitter section performs the task of distributing cells from the ATM stream among multiple ATM cell substreams. Each ATM cell substream, also referred to as an ATM substream, is forwarded a different ATU. The multi-pair multiplexer receiver section performs the task of recombining the ATM substreams to regain the original ATM stream.

In the exemplary system illustrated in FIG. **2**, two ADSL PHYs **160** and **170** are "bonded" together to transport a single ATM cell stream. However, it should be appreciated, that the number of ADSL PHYs "bonded" together can be easily expanded to any number ($N \geqq 2$) of ADSL PHYs thereby, for example, enabling higher ATM data rates. In addition to the two ADSL PHYs **160** and **170** that are bonded together, it should further be appreciated that in some instances in the same access node **100**, other ADSL PHYs may be operating in the traditional way. Obviously, the ADSL PHYs operating the traditional way do not need to be connected to the multi-pair multiplexer **140**. Thus, in general, it should be appreciated that any combination of "bonded" and unbonded, i.e. traditional, ADSL PHY's, may be configured between the access node **100** and the broadband network determination **200**. Furthermore, it should be appreciated that all of the ADSL PHYs can be bonded together.

In may ADSL systems, the logical interface between the ATM layer the PHY is based on UTOPIA Level 2 with a cell level handshake. This same UTOPIA Level 2 logical interface can also be used between the multi-pair multiplexer and the ATM layer and also between the multi-pair multiplexer and the PHY in the access node **100** and the broadband network termination **200**. Although, the above example and the remainder of this discussion will be directed toward the multi-pair multiplexer functions using a ADSL PHY, any version of DSL that has an ATM-TC, e.g., VDSL, SHDSL, or the like, may be used instead of, or conjunction with, the ADSL PHY.

FIG. **3** illustrates an exemplary multi-pair multiplexing transmitter according to this invention. The ATU-C and ATU-R multi-pair multiplexer box provide the same basic transmitter and receiver functions and thus can be summarized as one unit.

In particular, the exemplary multi-pair multiplexing transmitter **300** illustrated in FIG. **3** provides, but not limited to, accepting a single ATM stream **310** from the ATM layer and distributing the cells among N ATM substreams **320**, where $N \geqq 2$. Furthermore, the multi-pair multiplexing transmitter **300** maps each ATM cell substream to a different DSL con-

nection and provides as output these ATM cell substreams to the appropriate ADSL PHY (ATUx). For the exemplary multi-pair multiplexing transmitter **300** illustrated in FIG. **3**, the cells from the ATM stream **310** are distributed amongst the ATM substreams **320** based on the data rate of each DSL PHY.

The configuration of the multi-pair multiplexing transmitter **300** can be varied to, for example, provide an equal or unequal data rate on the DSL PHYs. FIG. **4** illustrates an exemplary embodiment where an equal data rate is applied to all of the DSL PHYs. In particular, if the data rate on all of the DSL PHYs is the same, then an equal number of ATM cells will be transported over every PHY connection. In this case, the multi-pair multiplexing transmitter **300** sends the first ATM cell to ATU**1 330**, the second ATM cell to ATU**2 340**, the third ATM cell to ATU**3 350**, and so on. For the multi-pair multiplexing transmitter **300** illustrated in FIG. **4**, N=3 and an equal data rate on all DSL PHYs is illustrated, therefore the input ATM cells from the ATM stream **310**, as discussed above, are distributed equally and sequentially among the DSL PHYs.

For the multi-pair multiplexing transmitter **300** illustrated in FIG. **5**, an unequal data rate is transported on the DSL PHYs. In particular, if a data rate on all the DSL PHYs is not equal, the ATM cells can be forward to the DSL PHYs, at, for example, a ratio that matches the ratios of the available PHY data rates. If, for example, N=2, as illustrated in FIG. **5**, and the data rate of the first DSL PHY **360** is two times the data rate of the second PHY **370**, then the multi-pair multiplexer **300** would send 2 ATM cells to the first DSL PHY, i.e., cells **1** and **2**, and then send 1 ATM cell to the second DSL PHY, i.e., cell **3**. However, in general, this basic concept can be expanded at least to include the situation where N>2 and to non-integer data rate ratios.

For example, in a two modem environment where there is a "high-speed" and a "low-speed" implementation, an exemplary ratio of N:1 where N=2 to 8 can be specified. This means that the "high-speed" modem will have eight times the cells as the "low-speed" modem. In this exemplary configuration, there are eight cells of receiver FIFO meaning that the entire "high-speed" receiver could be empted before needing to service the "low-speed" receiver.

FIG. **6** illustrates an exemplary multi-pair multiplexing receiver **400**. The exemplary multi-pair multiplexing receiver **400** provides, but is not limited to, accepting multiple ATM cell substreams from different DSL PHYs and recombining the ATM cells from the different ATM cell substreams to recreate the original ATM stream, which is passed to the ATM layer. In particular, and as illustrated in FIG. **6**, a plurality of ATM substreams are received by the multi-pair multiplexing receiver **400** and recombined into the original ATM stream. Specifically, as in the multi-pair multiplexing transmitter, the recombining of cells from the DSL PHYs depends on the data rates of the individual PHY connections. As in the embodiment discussed in relation to FIG. **4**, where all DSL PHYs had an equal data rate, the multi-pair multiplexing receiver **400** can perform the inverse of the transmitting multiplexer function and reconstruct the original ATM stream by taking one cell from each ATM substream and combining them in the appropriate order, as illustrated in FIG. **7**.

Similarly, as illustrated in relation to the multi-pair multiplexing transmitter **300** illustrated in FIG. **5**, where the DSL PHYs had an unequal data rate, if different ratios of data rates are used a variable number of cells will be taken from each ATM substream to reconstruct the original ATM stream in the multi-pair multiplexing receiver **400** as illustrated in FIG. **8**.

Furthermore, an in addition to the changes in data rate that are possible on the DSL PHYs, ATM cells transported over a DSL PHY can have different end-to-end delay (latency) based on several parameters. This potential latency difference between bonded PHYs places implementation requirements on the multi-pair multiplexer. In particular, the multi-pair multiplexer receiver must be able to reconstruct the ATM stream even if the ATM cells are not being received in the same order as they where transmitted.

For example, some of the exemplary reasons for having different delays over different DSL PHYs include, but are not limited, configuration latency which is based on the configuration of the DSL transmission parameters. Specifically, these parameters include the data rate, coding parameters, such as the coding method, codeword size, interleaving parameters, framing parameters, or the like.

ATM-TC latency is based on cell rate decoupling in the ATM-TC. Specifically, the ATM-TC block in ADSL transceivers performs cell rate decoupling by inserting idle cells according to the ITU Standard I.432, incorporated herein by reference in its entirety. This means that depending on the ATU timing and the state of the ATU buffers, an ATM cell that is sent over a DSL PHY will experience non-constant end-to-end delay (latency) through the PHY.

Wire latency is based on differences in the twisted wire pairs. Specifically, the DSL electrical signals can experience different delays based on the difference in length of the wire, the gauge of the wire, the number bridged taps, or the like.

Design latency is based on differences in the DSL PHY design. Specifically, the latency of the PHY can also depend on the design chosen by the manufacture.

Thus, as result of the different latencies in the PHYs, it is possible that an ATM cell that was sent over a DSL PHY may be received at the multi-pair multiplexing receiver after an ATM cell that was sent out later on a different DSL PHY.

FIG. **9** illustrates an example of variable delay based on the embodiment discussed in relation to FIG. **4**. Therefore, the exemplary multi-pair multiplexing receiver **500** should be able to accommodate at least these types of variations in delay. An exemplary method for dealing with the issue of delay is to have cell buffers (not shown) in the multi-pair multiplexing receiver **500** that can provide the ability to compensate for the variations in delay. As example, if there is a cell buffer that can hold several ATM cells on each input ATM substream path, the multi-pair multiplexing receiver **500** can simply wait until, for example, cell number **1** comes in path number one, while path number two will buffer cell number **2** and wait for cell number **1** to be received. This method requires a cell buffer on each ATM substream path at the input of the multi-pair multiplexing receiver **500**. The size of the cell buffer can be determined by, for example, the maximum difference in latency between the "bonded" PHYs. As an alternative, the buffer can be based on one large buffer with multiple pointers without effecting the operation of the system.

Another effective method of reducing the difference in latency between DSL PHYs is mandate that all DSL PHYs are configured with transmission parameters in order to provide the same configuration latency. An exemplary method of accomplishing the same configuration latency is by configuring the exact same data rate, coding parameters, interleaving parameters, etc. on all DSL PHYs. Alternatively, different PHYs can have, for example, different data rates but use the appropriate coding or interleaving parameters to have the same latency on all the bonded PHYs.

As an example, for Reed Solomon coding and interleaving functions as defined in ADSL standards G.992.1 and G.992.3,

incorporated herein by reference in their entirety, the latency due to these functions is defined as:

$$\text{Latency}=N*D/R,$$

where N is the number of bits in a codeword, D is the interleaver depth in codewords and R is the data in bits per second.

For example if N=1600 bits, i.e., 200 bytes, D=64 codewords and R=6400000 bps then:

$$\text{Latency}=1600*64/640000=0.016 \text{ seconds.}$$

Therefore if, for example, two PHYs have different data rates, R1 and R2 then, in order to bond these PHYs together and have the same configuration latency set:

$$N1*D1/R1=N2*D2/R2,$$

where N1 and N2 are the bits in a codeword for each PHY and D1 and D2 are the interleaver depths for each PHY.

This can also be rewritten as:

$$N1*D1=(R1/R2)*N2*D2.$$

Thus, in general, the N1, N1, N2 and D2 parameters must be chosen to satisfy the above equations and this can be accomplished in several ways.

For example, if the configuration latency is specified as 0.016 seconds, and R1=6400000 bps and R2=1600000 then, as described in the example above, N1 anss D1 can be configured as N1=1600 and D1=64. Therefore:

$$N2*D2=(R2/R1)*D1*N1=(1600000/6400000)*1600*64=1600*64/4.$$

Therefore, for example, N2 and D2 can be configured as (N2=1600, D2=16) or (N2=400, D2=64) or (N2=800, D2=32), etc.

Obviously the same methods can be applied to more than 2 PHYs with different data rates.

The ATM-TC receiver in ADSL systems is specified to discard ATM cells that are received with an incorrect cyclic redundancy check, e.g., (HEC). This means that if there are bit errors as the result of transmission over the ADSL channel, ATM cells will be discarded by the ATM-TC and not sent to the multi-pair multiplexing receiver. As a result of this type of error condition, ATM cells may be received out of order in the multi-pair multiplexing receiver.

FIG. **10** illustrates an exemplary multi-pair multiplexing receiver **500** with a single ATM cell lost due to PHY channel errors using the exemplary embodiment discussed in relation to FIG. **4**. In FIG. **10**, ATM cell number **5** was discarded by the second DSL PHY **510** due to, for example, a HEC error. Therefore, if the multi-pair multiplexing receiver **500** is not aware of this error, the ATM cells stream can not be reconstructed appropriately.

The exemplary systems and methods of this invention utilize a multi-pair cell counter to operate in the condition where the ATM cells are discarded by DSL PHY when, for example, HEC errors occur. The multi-pair multiplexing transmitter can embed the multi-pair cell counter in the header of each ATM cell after receiving the ATM cell from the ATM layer. At the receiver, the multi-pair multiplexing receiver reads the multi-pair cell counter and removes it from the header of the ATM cell prior to sending the ATM cell to the ATM layer. The multi-pair cell counter is a value that indicates the position of a particular ATM cell in the ATM cell stream.

In its simplest form, the multi-pair cell counter can be a modulo L counter that starts at, for example, zero and increments by one for each consecutive ATM cell up to a value L-1. For example, if L equals 256, the value of the multi-pair cell counter could start at zero and increment by one up to a value of 255. After 255, the multi-pair counter could be started at zero again, and so on.

As previously discussed, the multi-pair cell counter can be embedded in the ATM cell header of all the ATM cells in the ATM stream. FIG. **11** illustrates the multi-pair multiplexing transmitter **400** as discussed in relation to the example illustrated in FIG. **4**, with L equal to 4 and the multi-pair cell counter specified inside the ATM cell header. At the receiver, the multi-pair cell counter is read by the multi-pair multiplexing receiver and removed from the ATM cell header. The multi-pair multiplexing receiver uses the multi-pair cell counter to properly recombine the ATM cells to reconstruct the ATM stream. Therefore, as in the example above, where a cell was discarded by the DSL PHY, the multi-pair multiplexing receiver would be able to determine this error and the ATM cell(s) placed in the appropriate order.

FIG. **12** illustrates an example where the 5^{th} ATM cell in the ATM stream was discarded by the PHY. The 5^{th} ATM cell in the exemplary ATM stream has a multi-pair cell counter number equal to 0 and was sent on the second ATU. The exemplary multi-pair multiplexing receiver **500** can check the multi-pair cell count value of the ATU's ATM cell before inserting the cell back into the ATM stream. In this manner, when the multi-pair multiplexing receiver checks the ATM cell counter from the second ATU and reads a multi-pair cell count **3** instead of zero, the multi-pair multiplexing receiver can determine that the ATM cell with the multi-pair cell counter equal to 0 was discarded by the second ATU PHY. In this case, multi-pair multiplexing receiver will not take a cell from the ATU-2 ATM substream. Instead, the multi-pair multiplexing receiver will move to the next ATU in order to check the multi-pair cell count value, and insert the ATM cell back into the ATM stream if the multi-pair cell count is correct, and continue. Therefore, as a result of using the multi-pair cell counter, the multi-pair multiplexing receiver can properly reconstruct the original ATM cell stream even in the presence of ATM cell lost.

The exemplary main multi-pair cell parameter is the value of L. The appropriate value of L depends on the number of bonded PHYs (N) and the maximum number (M) of consecutive ATM cells that may be discarded by the PHY. The design constraint on L is that it must be large enough so that the multi-pair multiplexing receiver can still detect cell lost even when the maximum number of consecutive ATM cells are discarded by a PHY. This places the constraint that L>N*M. For example, if there are N=4 bonded PHYs, and the maximum number of consecutive ATM cells that may discarded by the PHY is M=50, then L>200. If, for example L is chosen to be equal to 256, then even when 50 consecutive ATM cells are lost, the multi-pair multiplexing receiver can accurately detect the error event.

There are several exemplary methods to embedding the multi-pair cell counter into the ATM cell header including, but not limited to, using the GFC field in the UNI ATM header. The GFC field is currently not used and is typically set to zero. The GFC field is a four bit field therefore the maximum value of L is 16. This could pose an issue when the channel has, for example, impulse noise and the PHY data rate is high resulting in cases where multiple ATM cells are often discarded by the PHY.

Therefore, as an alternative, bits in the VPI/VCI field can be used. The VPI field occupies 8 bits in the UNI header and identifies the route taken by the ATM cell. The VCI field occupies 16 bits in the UNI header and it identifies the circuit or connection number on the path. In order use the VPI/VCI field for the multi-pair cell counter, the multi-pair multiplex-

ing transmitter overwrites bits in the VPI/VCI field with the multi-pair cell counter value on a cell by cell bases. At the receiver, the multi-pair multiplexing receiver reads the multi-pair cell counter value and resets and overwrites the VPI/VCI back to the original value.

This method requires the multi-pair multiplexing receiver to have knowledge of the overwritten VPI/VCI bits. As an example, this can be accomplished by communicating the VPI/VCI fields of the ATM stream during initialization/configuration of the DSL connection or during configuration or re-configuration of the ATM connection. Since the VPI/VCI field has 24 bits, the L value for the multi-pair cell counter can be set to a very large number.

One exemplary method for embedding the multi-pair cell counter in the VPI/VCI field is to construct a table of all, or a portion of, possible VPI/VCI values that may be transported by the bonded DSL PHYs. This VPI/VCI table can, for example, be stored in the multi-pair multiplexing transmitters and receivers for all PHYs. The table maps a VPI/VCI value to a table index value that is also stored in the multi-pair multiplexing transmitters and receivers for all PHYs. If there are K VPI/VCI values being transported over the bonded DSL PHYs, the VPI/VCI value could be mapped to a number from zero to K-1. At the multi-pair multiplexing transmitter, the VPI/VCI value in the ATM header is replaced with the table index value. Since there are limited numbers of VPI/VCI going to a single subscriber, the table index value can utilize only a fraction of the 24 bits available in the VPI/VCI field. Therefore, the multi-pair multiplexing transmitter can use the remaining VPI/VCI bits to transport, for example, the multi-pair cell counter.

At the receiver, the multi-pair multiplexing receiver is multi-pair cell counter that reconstructs the ATM stream as discussed above. Additionally, the multi-pair multiplexing receiver can read the table index value in the ATM header and write the VPI/VCI value corresponding to the table index value as stored in the VPI/VCI table back into the VPI/VCI header field.

As a simple example, where only one VPI/VCI is being sent over the bonded DSL connection, the VPI/VCI table will have only one value. Therefore, in this case, it is not necessary to insert the table index value at the transmitter. The transmitter may use the bits in the VPI/VCI field for the multi-pair cell counter. At the receiver, the multi-pair cell counter is read and used to reconstruct the ATM stream. Since only one VPI/VCI value is being used, the receiver can reset the VPI/VCI field to the appropriate value prior to sending the ATM stream into the ATM layer. This approach can work, for example, with many consumer based employments of a DSL, since in most cases a single VPI/VCI is used.

As an alternative, consider a four VPI/VCI situation.

TABLE 1

VPI/VCI Table

VPI/VCI Value	Table Index Value (TIV)
Va (24 bit value)	0
Vb (24 bit value)	1
Vc (24 bit value)	2
Vd (24 bit value)	3

Table 1 contains an exemplary VPI/VCI table with four VPI/VCI addresses. Additionally, for the purpose of this example, the multi-pair cell counter is specified to be an eight bit counter, i.e., a modulo 255 counter.

FIG. **13** illustrates the format for the standard five bit ATM UNI header. The VPI/VCI values in Table 1 corresponds to the 24 bit VPI/VCI values in the UNI ATM header.

FIG. **14** illustrates an exemplary format of the ATM header after the multi-pair multiplexing transmitter has replace the VPI/VCI values with the table index value and then embedded the multi-pair cell counter in the VPI/VCI field. The first two bits the VPI/VCI field are used to transport the table index value (TIV) and the next eight bits are used to transport the multi-pair cell counter. The remaining bits can be reserved and can be used, for example, by the multi-pair multiplexing blocks for other purposes, such as the transportation of messages between the multi-pair multiplexing blocks, or the like.

At the receiver, the multi-pair multiplexing receiver reads the multi-pair cell counter value from the header in order to properly reconstruct the ATM stream. The multi-pair multiplexing receiver also reads the TIV in the ATM header and writes the VPI/VCI corresponding to the table index value as stored in the VPI/VCI table back into the VPI/VCI header field. As a result, at the output of the multi-pair multiplexing receiver, the ATM header can be completely reconstructed into the standard UNI format comprising the original data contents.

In this illustrative example, there were four VPI/VCI addresses being used in cells being transported over the bonded ADSL system. However, in many deployments, the VP is determined in the DSLAM, which means that the VPI field is the same for all packets. Therefore, in the case of terminating the VP and the DSLAM, the VP field could, for example, be used in transporting the TIV.

FIG. **15** illustrates an exemplary method of transporting ATM over DSL. In particular control begins in step S**100** and continues to step S**110**. In step S**110** the cell distributions are determined, for example, based on differing data rates between the DSL PHYs, or the like. Next, in step S**120** the cells from the ATM stream are assigned based on the determined cell distribution to the appropriate ATM TC cell stream. Then, in step S**130**, the cells are transmitted to a receiver. Control then continues to step S**140**.

In step S**140**, a receiver receives the cells. Next, in step S**150**, the ATM substreams are combined to reconstruct the ATM stream. In particular, in step S**152**, a determination is made whether there is a difference in latency between the DSL lines. If there are differential latency problems, control continues to step S**154** where the differential latency is compensated for by, for example, buffering, or the like. Otherwise, control jumps to step S**156**.

In step S**156**, a determination is made whether other errors are present in one or more of the substreams. If other errors, such as dropped cells, channel bit errors, or the like are present, control continues to step S**158** where the other errors are compensated for. Otherwise, control jumps to step S**160** where the control sequence ends.

The above-described ATM over DSL system can be implemented on a telecommunications device, such a modem, a DSL modem, an ADSL modem, a multicarrier transceiver, a VDSL modem, or the like, or on a separate programmed general purpose computer having a communications device. Additionally, the systems and methods of this invention can be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, modem, transmitter/receiver, or the like. In general, any device capable of implementing a state machine that is in turn capable of imple-

menting the flowchart illustrated herein can be used to implement the various ATM over DSL methods according to this invention.

Furthermore, the disclosed methods may be readily implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed ATM over DSL system may be implemented partially or fully in hardware using standard logic circuits or VLSI design. Whether software or hardware is used to implement the systems in accordance with this invention is dependent on the speed and/or efficiency requirements of the system, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The ATM over DSL systems and methods illustrated herein however can be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods may be readily implemented in software executed on programmed general purpose computer, a special purpose computer, a microprocessor, or the like. In these instances, the systems and methods of this invention can be implemented as program embedded on personal computer such as JAVA® or CGI script, as a resource residing on a server or graphics workstation, as a routine embedded in a dedicated ATM over DSL system, or the like. The ATM over DSL system can also be implemented by physically incorporating the system and method into a software and/or hardware system, such as the hardware and software systems of a communications transceiver.

It is, therefore, apparent that there has been provided, in accordance with the present invention, systems and methods for ATM over DSL. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable arts. Accordingly, it is intended to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and scope of this invention.

We claim:

1. A method comprising:

utilizing at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers, wherein a data rate for a first of the plurality of bonded transceivers is different than a data rate for a second of the plurality of bonded transceivers.

2. The method of claim **1**, wherein the at least one transmission parameter value is a Reed Solomon Coding parameter value, an interleaving parameter value, a coding parameter value, a codeword size value or a framing parameter value.

3. The method of claim **1**, wherein the bonded transceivers are transporting cells or ATM cells.

4. The method of claim **1**, wherein the bonded transceivers are transporting packets, Ethernet packets or IP packets.

5. The method of claim **1**, wherein the at least one transmission parameter value for the first of the plurality of bonded transceivers is a first Reed Solomon Coding parameter value, and the at least one transmission parameter value for the second of the plurality of bonded transceivers is a different Reed Solomon Coding parameter value.

6. The method of claim **5**, wherein the first Reed Solomon Coding parameter value is less than the different Reed Solomon Coding parameter value when the data rate for the first of the plurality of bonded transceivers is less than the data rate for the second of the plurality of bonded transceivers.

7. The method of claim **1**, wherein the at least one transmission parameter value for the first of the plurality of bonded transceivers is a first interleaving parameter value, and the at least one transmission parameter value for the second of the plurality of bonded transceivers is a different interleaving parameter value.

8. The method of claim **7**, wherein the first interleaving parameter value is less than the different interleaving parameter value when the data rate for the first of the plurality of bonded transceivers is less than the data rate for the second of the plurality of bonded transceivers.

9. A method comprising:

selecting at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers, wherein a data rate of a first of the plurality of bonded transceivers is different than a data rate of a second of the plurality of bonded transceivers.

10. The method of claim **9**, wherein the at least one transmission parameter value is a Reed Solomon Coding parameter value, an interleaving parameter value, a coding parameter value, a codeword size value or a framing parameter value.

11. The method of claim **9**, wherein the bonded transceivers are transporting cells or ATM cells.

12. The method of claim **9**, wherein the bonded transceivers are transporting packets, Ethernet packets or IP packets.

13. The method of claim **9**, wherein the at least one transmission parameter value for the first of the plurality of bonded transceivers is a first Reed Solomon Coding parameter value, and the at least one transmission parameter value for the second of the plurality of bonded transceivers is a different Reed Solomon Coding parameter value.

14. The method of claim **13**, wherein the first Reed Solomon Coding parameter value is less than the different Reed Solomon Coding parameter value when the data rate for the first of the plurality of bonded transceivers is less than the data rate for the second of the plurality of bonded transceivers.

15. The method of claim **9**, wherein the at least one transmission parameter value for the first of the plurality of bonded transceivers is a first interleaving parameter value, and the at least one transmission parameter value for the second of the plurality of bonded transceivers is a different interleaving parameter value.

16. The method of claim **15**, wherein the first interleaving parameter value is less than the different interleaving parameter value when the data rate for the first of the plurality of bonded transceivers is less than the data rate for the second of the plurality of bonded transceivers.

17. A plurality of bonded transceivers, each bonded transceiver utilizing at least one transmission parameter value to reduce a difference in latency between the bonded transceivers, wherein a data rate for a first of the bonded transceivers is different than a data rate for a second of the bonded transceivers.

18. The transceivers of claim **17**, wherein the at least one transmission parameter value is a Reed Solomon Coding parameter value, an interleaving parameter value, a coding parameter value, a codeword size value or a framing parameter value.

19. The transceivers of claim **17**, wherein the transceivers are capable of transporting cells or ATM cells.

20. The transceivers of claim **17**, wherein the transceivers are capable of transporting packets, Ethernet packets or IP packets.

21. The transceiver of claim **17**, wherein the at least one transmission parameter value for the first transceiver is a first Reed Solomon Coding parameter value that is different than a second Reed Solomon Coding parameter value for the second transceiver.

22. The transceivers of claim **21**, wherein the first Reed Solomon Coding parameter value is less than the second Reed Solomon Coding parameter value when the data rate for the first transceiver is less than the data rate for the second transceiver.

23. The transceivers of claim **17**, wherein the at least one transmission parameter value for the first transceiver is a first interleaving parameter value that is different than a second interleaving parameter value for the second transceiver.

24. The transceivers of claim **23**, wherein the first interleaving parameter value is less than the second interleaving parameter value when the data rate for the first transceiver is less than the data rate for the second transceiver.

25. A plurality of bonded transceivers, each bonded transceiver selecting at least one transmission parameter value to reduce a difference in latency between the bonded transceivers, wherein a data rate for a first of the bonded transceivers is different than a data rate for a second of the bonded transceivers.

26. The transceivers of claim **25**, wherein the at least one transmission parameter value is a Reed Solomon Coding parameter value, an interleaving parameter value, a coding parameter value, a codeword size value or a framing parameter value.

27. The transceivers of claim **25**, wherein the transceivers are is capable of transporting cells or ATM cells.

28. The transceivers of claim **25**, wherein the transceivers are capable of transporting packets, Ethernet packets or IP packets.

29. The transceivers of claim **25**, wherein the at least one transmission parameter value for the first transceiver is a first Reed Solomon Coding parameter value that is different than a second Reed Solomon Coding parameter value for the second transceiver.

30. The transceivers of claim **29**, wherein the first Reed Solomon Coding parameter value is less than the second Reed Solomon Coding parameter value when the data rate for the first transceiver is less than the data rate for the second transceiver.

31. The transceivers of claim **25**, wherein the at least one transmission parameter value for the first transceiver is a first interleaving parameter value that is different than a second interleaving parameter value for the second transceiver.

32. The transceivers of claim **31**, wherein the first interleaving parameter value is less than the second interleaving parameter value when the data rate for the first transceiver is less than the data rate for the second transceiver.

33. A storage media having computer executable instructions stored thereon that:

utilize at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers, wherein a data rate for a first of the plurality of bonded transceivers is different than a data rate for a second of the plurality of bonded transceivers.

34. The media of claim **33**, wherein the at least one transmission parameter value is a Reed Solomon Coding parameter value, an interleaving parameter value, a coding parameter value, a codeword size value or a framing parameter value.

35. The media of claim **33**, wherein the bonded transceivers are transporting cells or ATM cells.

36. The media of claim **33**, wherein the bonded transceivers are transporting packets, Ethernet packets or IP packets.

37. A storage media having computer executable instructions stored thereon that:

select at least one transmission parameter value, for each transceiver in a plurality of bonded transceivers, to reduce a difference in latency between the bonded transceivers, wherein a data rate of a first of the plurality of bonded transceivers is different than a data rate of a second of the plurality of bonded transceivers.

38. The media of claim **37**, wherein the at least one transmission parameter value is a Reed Solomon Coding parameter value, an interleaving parameter value, a coding parameter value, a codeword size value or a framing parameter value.

39. The media of claim **37**, wherein the bonded transceivers are transporting cells or ATM cells.

40. The media of claim **37**, wherein the bonded transceivers are transporting packets, Ethernet packets or IP packets.

41. A communications system comprising:

a plurality of bonded communication means,

each bonded communication means utilizing at least one transmission parameter value to reduce a difference in latency between the bonded communication means, wherein a data rate for a first of the plurality of bonded communication means is different than a data rate for a second of the plurality of bonded communication means.

42. A communications system comprising:

a plurality of bonded communication means,

each bonded communication means selecting at least one transmission parameter value to reduce a difference in latency between the bonded communication means, wherein a data rate of a first of the plurality of bonded communication means is different than a data rate of a second of the plurality of bonded transmission means.

* * * * *

US007570686B2

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Krinsky et al.

(10) **Patent No.: US 7,570,686 B2**
(45) **Date of Patent: Aug. 4, 2009**

(54) **SYSTEMS AND METHODS FOR ESTABLISHING A DIAGNOSTIC TRANSMISSION MODE AND COMMUNICATING OVER THE SAME**

(75) Inventors: **David M Krinsky**, Acton, MA (US); **Robert Edmund Pizzano, Jr.**, Stoneham, MA (US)

(73) Assignee: **Aware, Inc.**, Bedford, MA (US)

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(51) **Int. Cl.**
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H04L 12/26 (2006.01)

(52) **U.S. Cl.** **375/222**; 370/252

(58) **Field of Classification Search** 375/222, 375/224–225, 227, 220, 284; 370/252, 282, 370/241; 379/22.02, 22.04, 27.01, 27.03
See application file for complete search history.

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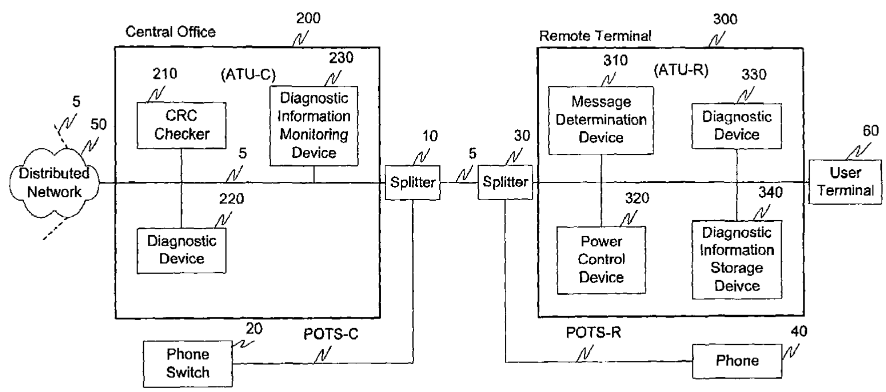
Primary Examiner—Khanh C Tran
(74) *Attorney, Agent, or Firm*—Sheridan Ross P.C.; Jason H. Vick

(57) **ABSTRACT**

Upon detection of a trigger, such as the exceeding of an error threshold or the direction of a user, a diagnostic link system enters a diagnostic information transmission mode. This diagnostic information transmission mode allows for two modems to exchange diagnostic and/or test information that may not otherwise be exchangeable during normal communication. The diagnostic information transmission mode is initiated by transmitting an initiate diagnostic link mode message to a receiving modem accompanied by a cyclic redundancy check (CRC). The receiving modem determines, based on the CRC, if a robust communications channel is present. If a robust communications channel is present, the two modems can initiate exchange of the diagnostic and/or test information. Otherwise, the transmission power of the transmitting modem is increased and the initiate diagnostic link mode message re-transmitted to the receiving modem until the CRC is determined to be correct.

41 Claims, 2 Drawing Sheets



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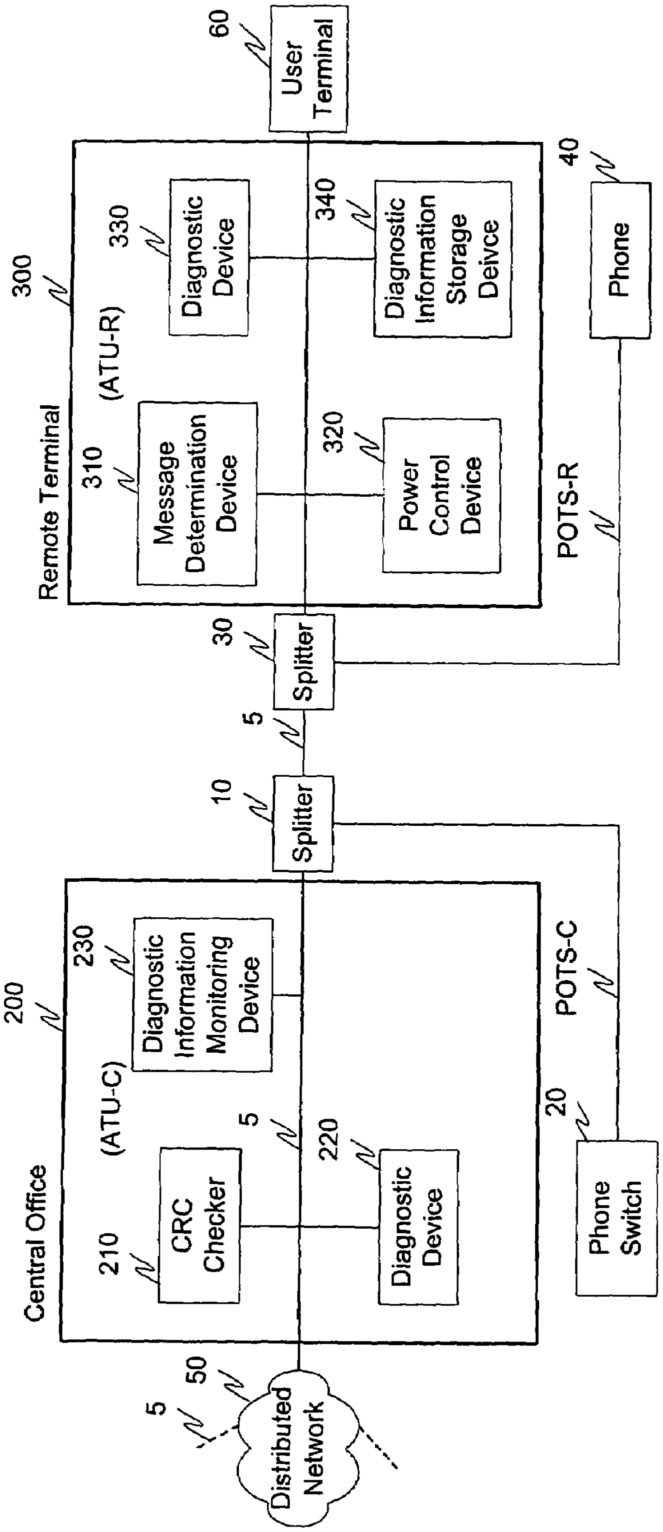
User Terminal
60
300
Remote Terminal
(ATU-R)
330
Diagnostic Device
340
Diagnostic Information Storage Deivce
310
Message Determination Device
320
Power Control Device
40
Phone
POTS-R
30
Splitter
5
10
Splitter
200
Central Office
(ATU-C)
230
Diagnostic Information Monitoring Device
210
CRC Checker
5
220
Diagnostic Device
POTS-C
20
Phone Switch
50
5
Distributed Network

Fig. 1

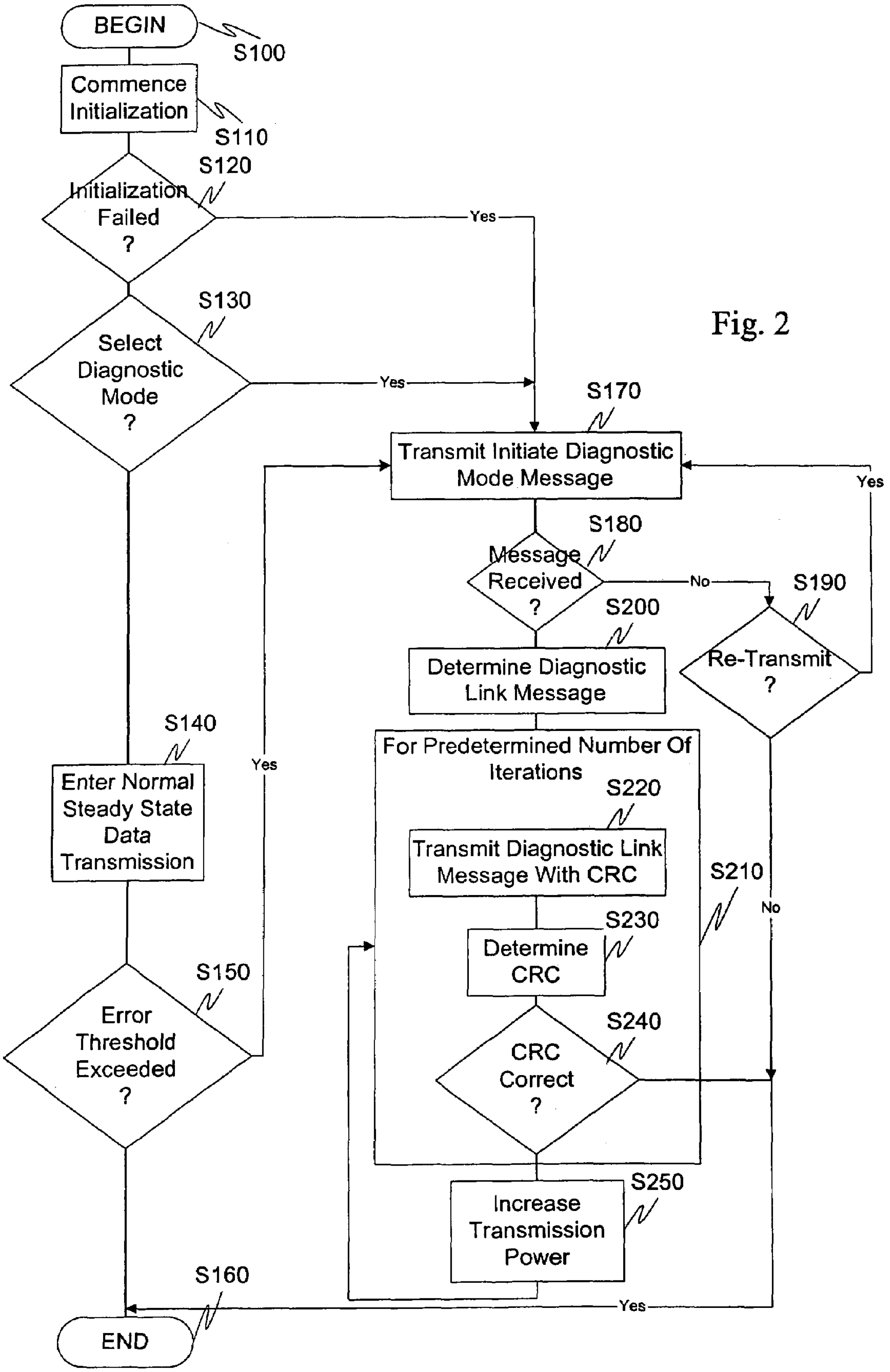
BEGIN
S100
Commence Initialization
S110
S120
Initialization Failed ?
Yes
S130
Select Diagnostic Mode ?
Yes
S170
Transmit Initiate Diagnostic Mode Message
Yes
S180
Message Received ?
No
S190
Re-Transmit ?
S200
Determine Diagnostic Link Message
S140
Enter Normal Steady State Data Transmission
Yes
For Predetermined Number Of Iterations
S220
Transmit Diagnostic Link Message With CRC
S210
No
S230
Determine CRC
S150
Error Threshold Exceeded ?
S240
CRC Correct ?
S250
Increase Transmission Power
S160
Yes
END

Fig. 2

SYSTEMS AND METHODS FOR ESTABLISHING A DIAGNOSTIC TRANSMISSION MODE AND COMMUNICATING OVER THE SAME

RELATED APPLICATION DATA

This application is a Divisional Application of U.S. application Ser. No. 09/755,173 entitled "Systems and Methods For Establishing A Diagnostic Transmission Mode And Communicating Over the Same" filed Jan. 8, 2001, which claims benefit of Provisional Application Nos. 60/224,308 filed Aug. 10, 2000 and 60/174,865 filed Jan. 7, 2000 and incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

This invention relates to test and diagnostic information. In particular, this invention relates to a robust system and method for communicating diagnostic information.

BACKGROUND OF THE INVENTION

The exchange of diagnostic and test information between transceivers in a telecommunications environment is an important part of a telecommunications, such as an ADSL, deployment. In cases where the transceiver connection is not performing as expected, for example, where the data rate is low, where there are many bit errors, or the like, it is necessary to collect diagnostic and test information from the remote transceiver. This is performed by dispatching a technician to the remote site, e.g., a truck roll, which is time consuming and expensive.

In DSL technology, communications over a local subscriber loop between a central office and a subscriber premises is accomplished by modulating the data to be transmitted onto a multiplicity of discrete frequency carriers which are summed together and then transmitted over the subscriber loop. Individually, the carriers form discrete, non-overlapping communication subchannels of limited bandwidth. Collectively, the carriers form what is effectively a broadband communications channel. At the receiver end, the carriers are demodulated and the data recovered.

DSL systems experience disturbances from other data services on adjacent phone lines, such as, for example, ADSL, HDSL, ISDN, T1, or the like. These disturbances may commence after the subject ADSL service is already initiated and, since DSL for internet access is envisioned as an always-on service, the effect of these disturbances must be ameliorated by the subject ADSL transceiver.

SUMMARY OF THE INVENTION

The systems and methods of this invention are directed toward reliably exchanging diagnostic and test information between transceivers over a digital subscriber line in the presence of voice communications and/or other disturbances. For simplicity of reference, the systems and methods of the invention will hereafter refer to the transceivers generically as modems. One such modem is typically located at a customer premises such as a home or business and is "downstream" from a central office with which it communicates. The other modem is typically located at the central office and is "upstream" from the customer premises. Consistent with industry practice, the modems are often referred to as "ATU-R" ("ADSL transceiver unit, remote," i.e., located at the customer premises) and "ATU-C" ("ADSL transceiver unit, central office" i.e., located at the central office). Each modem includes a transmitter section for transmitting data and a receiver section for receiving data, and is of the discrete multitone type, i.e., the modem transmits data over a multiplicity of subchannels of limited bandwidth. Typically, the upstream or ATU-C modem transmits data to the downstream or ATU-R modem over a first set of subchannels, which are usually the higher-frequency subchannels, and receives data from the downstream or ATU-R modem over a second, usually smaller, set of subchannels, commonly the lower-frequency subchannels. By establishing a diagnostic link mode between the two modems, the systems and methods of this invention are able to exchange diagnostic and test information in a simple and robust manner.

In the diagnostic link mode, the diagnostic and test information is communicated using a signaling mechanism that has a very high immunity to noise and/or other disturbances and can therefore operate effectively even in the case where the modems could not actually establish an acceptable connection in their normal operational mode.

For example, if the ATU-C and/or ATU-R modem fail to complete an initialization sequence, and are thus unable to enter a normal steady state communications mode, where the diagnostic and test information would normally be exchanged, the modems according to the systems and methods of this invention enter a robust diagnostic link mode. Alternatively, the diagnostic link mode can be entered automatically or manually, for example, at the direction of a user. In the robust diagnostic link mode, the modems exchange the diagnostic and test information that is, for example, used by a technician to determine the cause of a failure without the technician having to physically visit, i.e., a truckroll to, the remote site to collect data.

The diagnostic and test information can include, for example, but is not limited to, signal to noise ratio information, equalizer information, programmable gain setting information, bit allocation information, transmitted and received power information, margin information, status and rate information, telephone line condition information, such as the length of the line, the number and location of bridged taps, a wire gauge, or the like, or any other known or later developed diagnostic or test information that may be appropriate for the particular communications environment. For example, the exchanged diagnostic and test information can be directed toward specific limitations of the modems, to information relating to the modem installation and deployment environment, or to other diagnostic and test information that can, for example, be determined as needed which may aid in evaluating the cause of a specific failure or problem. Alternatively, the diagnostic and test information can include the loop length and bridged tap length estimations as discussed in U.S. patent application Ser. No. 09/755,172 now became U.S. Pat. No. 6,865,221, filed herewith and incorporated herein by reference in its entirety.

For example, an exemplary embodiment of the invention illustrates the use of the diagnostic link mode in the communication of diagnostic information from the remote terminal (RT) transceiver, e.g., ATU-R, to the central office (CO) transceiver, e.g., ATU-C. Transmission of information from the remote terminal to the central office is important since a typical ADSL service provider is located in the central office and would therefore benefit from the ability to determine problems at the remote terminal without a truckroll. However, it is to be appreciated, that the systems and the methods of this invention will work equally well in communications from the central office to the remote terminal.

These and other features and advantages of this invention are described in or are apparent from the following detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the invention will be described in detail, with reference to the following figures wherein:

FIG. **1** is a functional block diagram illustrating an exemplary communications system according to this invention; and

FIG. **2** is a flowchart outlining an exemplary method for communicating diagnostic and test information according to this invention.

DETAILED DESCRIPTION OF THE INVENTION

For ease of illustration the following description will be described in relation to the CO receiving diagnostic and test information from the RT. In the exemplary embodiment, the systems and methods of this invention complete a portion of the normal modem initialization before entering into the diagnostic link mode. The systems and methods of this invention can enter the diagnostic link mode manually, for example, at the direction of a technician or a user after completing a portion of initialization. Alternatively, the systems and methods of this invention can enter the diagnostic link mode automatically based on, for example, a bit rate failure, a forward error correction or a CRC error during showtime, e.g., the normal steady state transmission mode, or the like. The transition into the diagnostic link mode is accomplished by transmitting a message from the CO modem to the RT modem indicating that the modems are to enter into the diagnostic link mode, as opposed to transitioning into the normal steady state data transmission mode. Alternatively, the transition into the diagnostic link mode is accomplished by transmitting a message from the RT modem to the CO modem indicating that the modems are to enter into the diagnostic link mode as opposed to transitioning into the normal steady state data transmission mode. For example, the transition signal uses an ADSL state transition to transition from a standard ADSL state to a diagnostic link mode state.

In the diagnostic link mode, the RT modem sends diagnostic and test information in the form of a collection of information bits to the CO modem that are, for example, modulated by using one bit per DTM symbol modulation, as is used in the C-Rates**1** message in the ITU and ANSI ADSL standards, where the symbol may or may not include a cyclic prefix. Other exemplary modulation techniques include Differential Phase Shift Keying (DPSK) on a subset or all the carriers, as specified in, for example, ITU standard G.994.1, higher order QAM modulation (>1 bit per carrier), or the like.

In the one bit per DMT symbol modulation message encoding scheme, a bit with value 0 is mapped to the REVERB**1** signal and a bit with a value of 1 mapped to a SEGUE**1** signal. The REVERB**1** and SEGUE**1** signals are defined in the ITU and ANSI ADSL standards. The REVERB**1** signal is generated by modulating all of the carriers in the multicarrier system with a known pseudo-random sequence thus generating a wideband modulated signal. The SEGUE**1** signal is generated from a carrier by 180 degree phase reversal of the REVERB**1** signal. Since both signals are wideband and known in advance, the receiver can easily detect the REVERB**1** and SEGUE**1** signal using a simple matched filter in the presence of large amounts of noise and other disturbances

TABLE 1

Exemplary Message Variables
Data Sent in the Diag Link
Train Type
ADSL Standard
Chip Type
Vendor ID
Code Version
Average Reverb Received Signal
Programmable gain amplifier (PGA) Gain - Training
Programmable gain amplifier PGA Gain - Showtime
Filter Present during Idle Channel Calculation
Average Idle Channel Noise
Signal to Noise during Training
Signal to Noise during Showtime
Bits and Gains
Data Rate
Framing Mode
Margin
Reed-Solomon Coding Gain
QAM Usage
Frequency Domain Equalizer (FDQ) Coefficients
Gain Scale
Time domain equalizer (TDQ) Coefficients
Digital Echo Canceller (DEC) Coefficients

Table 1 shows an example of a data message that can be sent by the RT to the CO during the diagnostic link mode. In this example, the RT modem sends 23 different data variables to the CO. Each data variable contains different items of diagnostic and test information that are used to analyze the condition of the link. The variables may contain more than one item of data. For example, the *Average Reverb Signal* contains the power levels per tone, up to, for example, 256 entries, detected during the ADSL Reverb signal. Conversely, the *PGA Gain—Training* is a single entry, denoting the gain in dB at the receiver during the ADSL training.

Many variables that represent the type of diagnostic and test information that are used to analyze the condition of the link are sent from the RT modem to the CO modem. These variables can be, for example, arrays with different lengths depending on, for example, information in the initiate diagnostic mode message. The systems and methods of this invention can be tailored to contain many different diagnostic and test information variables. Thus, the system is fully configurable, allowing subsets of data to be sent and additional data variables to be added in the future. Therefore, the message length can be increased or decreased, and diagnostic and test information customized, to support more or less variables as, for example, hardware, the environment and/or the telecommunications equipment dictates.

Therefore, it is to be appreciated, that in general the variables transmitted from the modem being tested to the receiving modem can be any combination of variables which allow for transmission of test and/or diagnostic information.

FIG. **1** illustrates an exemplary embodiment of the additional modem components associated with the diagnostic link mode. In particular, the diagnostic link system **100** comprises a central office modem **200** and a remote terminal modem **300**. The central office modem **200** comprises, in addition to the standard ATU-C components, a CRC checker **210**, a diagnostic device **220**, and a diagnostic information monitoring device **230**. The remote terminal modem **300** comprises, in addition to the standard components associated with an ATU-R, a message determination device **310**, a power control device **320**, a diagnostic device **330** and a diagnostic information storage device **340**. The central office modem **200** and the remote terminal model **300** are also connected, via link **5**,

to a splitter **10** for a phone switch **20**, and a splitter **30** for a phone **40**. Alternatively, the ATU-R can operate without a splitter, e.g., splitterless, as specified in ITU standard G.992.2 (G.lite) or with an in-line filter in series with the phone **40**. In addition, the remote terminal modem **300**, can also be connected to, for example, one or more user terminals **60**. Additionally, the central office modem **200** can be connected to one or more distributed networks **50**, via link **5**, which may or may not also be connected to one or more other distributed networks.

While the exemplary embodiment illustrated in FIG. **1** shows the diagnostic link system **100** for an embodiment in which the remote terminal modem **300** is communicating test and diagnostic information to the central office **200**, it is to be appreciated that the various components of the diagnostic link system can be rearranged such that the diagnostic and test information can be forwarded from the central office **200** to the remote terminal modem **300**, or, alternatively, such that both modems can send and receive diagnostic and/or test information. Furthermore, it is to be appreciated, that the components of the diagnostic link system **100** can be located at various locations within a distributed network, such as the POTS network, or other comparable telecommunications network. Thus, it should be appreciated that the components of the diagnostic link system **100** can be combined into one device for respectively transmitting, receiving, or transmitting and receiving diagnostic and/or test information. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the diagnostic link system **100** can be arranged at any location within a telecommunications network and/or modem without affecting the operation of the system.

The links **5** can be a wired or wireless link or any other known or later developed element(s) that is capable of supplying and communicating electronic data to and from the connected elements. Additionally, the user terminal **60** can be, for example, a personal computer or other device allowing a user to interface with and communicate over a modem, such as a DSL modem. Furthermore, the systems and method of this invention will work equally well with splitterless and low-pass multicarrier modem technologies.

In operation, the remote terminal **300**, commences its normal initialization sequence. The diagnostic device **330** monitors the initialization sequence for a failure. If there is a failure, the diagnostic device **330** initiates the diagnostic link mode. Alternatively, a user or, for example, a technician at the CO, can specify that the remote terminal **300** enter into the diagnostic link mode after completing a portion of an initialization. Alternatively still, the diagnostic device **330** can monitor the normal steady state data transmission of the remote terminal, and upon, for example, an error threshold being exceeded, the diagnostic device **330** will initiate the diagnostic link mode.

Upon initialization of the diagnostic link mode, the diagnostic device **330**, in cooperation with the remote terminal **300** will transmit an initiate diagnostic link mode message from the remote terminal to the central office **200** (RT to CO). Alternatively, the central office modem **200** can transmit an initiate diagnostic link mode message to the remote terminal modem **300**. If the initiate diagnostic link mode message is received by the central office **200**, the diagnostic device **330**, in cooperation with the message determination device **310**, determines a diagnostic link message to be forwarded to the central office **200**. For example, the diagnostic link message can include test information that has been assembled during, for example, the normal ADSL initialization procedure. The diagnostic and/or test information can include, but is not limited to, the version number of the diagnostic link mode, the length of the diagnostic and/or test information, the communications standard, such as the ADSL standard, the chipset type, the vendor identifications, the ATU version number, the time domain received reverb signal, the frequency domain reverb signal, the amplifier settings, the CO transmitter power spectral density, the frequency domain received idle channel, the signal to noise ratio, the bits and gains and the upstream and downstream transmission rates, or the like.

If the initiate diagnostic link mode message is not received by the central office **200**, the initiate diagnostic link mode message can, for example, be re-transmitted a predetermined number of iterations until a determination is made that it is not possible to establish a connection.

Assuming the initiate diagnostic link mode message is received, then, for a predetermined number of iterations, the diagnostic device **330**, in cooperation with the remote terminal modem **300** and the diagnostic information storage device **340**, transmits the diagnostic link message with a cyclic redundancy check (CRC) to the central office modem **200**. However, it is to be appreciated that in general, any error detection scheme, such as bit error detection, can be used without affecting the operation of the system. The central office **200**, in cooperation with the CRC checker **210**, determines if the CRC is correct. If the CRC is correct, the diagnostic information stored in the diagnostic information storage device **340** has been, with the cooperation of the diagnostic device **330**, and the remote terminal modem **300**, forwarded to the central office **200** successfully.

If, for example, the CRC checker **210** is unable to determine the correct CRC, the diagnostic device **330**, in cooperation with power control device **320**, increases the transmission power of the remote terminal **300** and repeats the transmission of the diagnostic link message from the remote terminal **300** to the central office **200**. This process continues until the correct CRC is determined by the CRC checker **210**.

The maximum power level used for transmission of the diagnostic link message can be specified by, for example, the user or the ADSL service operator. If the CRC checker **210** does not determine a correct CRC at the maximum power level and the diagnostic link mode can not be initiated then other methods for determining diagnostic information are utilized, such as dispatching a technician to the remote site, or the like.

Alternatively, the remote terminal **300**, with or without an increase in the power level, can transmit the diagnostic link message several times, for example, **4** times. By transmitting the diagnostic link message several times, the CO modem **200** can use, for example, a diversity combining scheme to improve the probability of obtaining a correct CRC from the received diagnostic link message(s).

Alternatively, as previously discussed, the central office **200** comprises a diagnostic information monitoring device **230**. The remote terminal **300** can also include a diagnostic information monitoring device. One or more of these diagnostic information monitoring devices can monitor the normal steady state data transmission between the remote terminal **300** and the central office **200**. Upon, for example, the normal steady state data transmission exceeded a predetermined error threshold, the diagnostic information monitoring device can initiate the diagnostic link mode with the cooperation of the diagnostic device **300** and/or the diagnostic device **220**.

FIG. **2** illustrates an exemplary method for entering a diagnostic link mode in accordance with this invention. In particular, control begins in step S**100** and continues to step S**110**. In step S**110**, the initialization sequence is commenced.

Next, in step **S120**, if an initialization failure is detected, control continues to step S**170**. Otherwise, control jumps to step S**130**. In step S**130**, a determination is made whether the diagnostic link mode has been selected. If the diagnostic link mode has been selected, control continues to step S**170**, otherwise, control jumps to step S**140**.

In step S**170**, the initiate diagnostic link mode message is transmitted from, for example, the remote terminal to the central office. Next, in step S**180**, a determination is made whether the initiate diagnostic mode message has been received by the CO. If the initiate diagnostic mode message has been received by the CO, control jumps to step S**200**. Otherwise, control continues to step S**190**. In step S**190**, a determination is made whether to re-transmit the initiate diagnostic mode message, for example, based on whether a predetermined number of iterations have already been completed. If the initiate diagnostic mode message is to be re-transmitted, control continues back to step S**170**. Otherwise, control jumps to step S**160**.

In step S**200**, the diagnostic link message is determined, for example, by assembling test and diagnostic information about one or more of the local loop, the modem itself, the telephone network at the remote terminal, or the like. Next, in step S**210**, for a predetermined number of iterations, steps S**220**-S**240** are completed. In particular, in step S**220** a diagnostic link message comprising a CRC is transmitted to, for example, the CO. Next, in step S**230**, the CRC is determined. Then, in step S**240**, a determination is made whether the CRC is correct. If the CRC is correct, the test and/or diagnostic information has been successfully communicated and control continues to step S**160**.

Otherwise, if step S**210** has completed the predetermined number of iterations, control continues to step S**250**. In step S**250**, the transmission power is increased and control continues back to step S**210**. Alternatively, as previously discussed, the diagnostic link message may be transmitted a predetermined number of times, with our without a change in the transmission power.

In step S**140**, the normal steady state data transmission is entered into between two modems, such as the remote terminal and the cental office modems. Next, in step S**150**, a determination is made whether an error threshold during the normal steady state data transmission has been exceeded. If the error threshold has been exceeded, control continues to step S**170**. Otherwise, control jumps to step S**160**. In step S**160**, the control sequence ends.

As shown in FIG. **1**, the diagnostic link mode system can be implemented either on a single program general purpose computer, a modem, such as a DSL modem, or a separate program general purpose computer having a communications device. However, the diagnostic link system can also be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element, an ASIC or other integrated circuit, a digital signal processor, a hardwired electronic or logic circuit such as a discrete element circuit, a programmed logic device such as a PLD, PLA, FPGA, PAL, or the like, and associated communications equipment. In general, any device capable of implementing a finite state machine that is capable of implementing the flowchart illustrated in FIG. **2** can be used to implement a diagnostic link system according to this invention.

Furthermore, the disclosed method may be readily implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer, workstation, or modem hardware platforms. Alternatively, the disclosed diagnostic link system may be implemented partially or fully in hardware using standard logic circuits or a VLSI design. Other software or hardware can be used to implement the systems in accordance with this invention depending on the speed and/or efficiency requirements of the systems, the particular function, and a particular software or hardware systems or microprocessor or microcomputer systems being utilized. The diagnostic link system and methods illustrated herein however, can be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods can be readily implemented as software executed on a programmed general purpose computer, a special purpose computer, a microprocessor, or the like. In these instances, the methods and systems of this invention can be implemented as a program embedded on a modem, such a DSL modem, as a resource residing on a personal computer, as a routine embedded in a dedicated diagnostic link system, a central office, or the like. The diagnostic link system can also be implemented by physically incorporating the system and method into a software and/or hardware system, such as a hardware and software systems of a modem, a general purpose computer, an ADSL line testing device, or the like.

It is, therefore, apparent that there is provided in accordance with the present invention, systems and methods for transmitting a diagnostic link message. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable arts. Accordingly, applicants intend to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and the scope of this invention.

What is claimed is:

1. In a multicarrier modulation transceiver, a method of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

transmitting or receiving at the multicarrier modulation transceiver an initiate diagnostic mode message; and

transmitting from the multicarrier modulation transceiver a diagnostic message using multicarrier modulation, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and each bit in the diagnostic message is mapped to at least one DMT symbol, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

2. The method of claim **1**, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

3. The method of claim **1**, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

4. The method of claim 1, wherein the transceiver is a central office modem or a remote terminal modem.

5. A diagnostic system capable of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

a transceiver capable of transmitting or receiving an initiate diagnostic mode message; and

a message determination module capable of determining and, in cooperation with the transceiver, transmitting a diagnostic message from the transceiver, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and each bit in the diagnostic message is mapped to at least one DMT signal, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

6. The system of claim 5, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

7. The system of claim 5, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

8. The system of claim 5, wherein the transceiver is a central office modem or a remote terminal modem.

9. A multicarrier communication transceiver capable of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

means for transmitting or receiving at the multicarrier communication transceiver an initiate diagnostic mode message; and

means for transmitting from the multicarrier communication transceiver a diagnostic message using multicarrier modulation, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and each bit in the diagnostic message is mapped to at least one DMT symbol, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

10. The transceiver of claim 9, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

11. The transceiver of claim 9, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

12. The transceiver of claim 9, wherein the transceiver is a central office modem or a remote terminal modem.

13. In a multicarrier communication transceiver, a protocol for communicating diagnostic information over a communication channel using multicarrier modulation comprising:

transmitting or receiving at the multicarrier communication transceiver an initiate diagnostic mode message; and

transmitting from the multicarrier communication transceiver a diagnostic message using multicarrier modulation, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and each bit in the diagnostic message is mapped to at least one DMT symbol, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

14. The protocol of claim 13, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

15. The protocol of claim 13, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

16. The protocol of claim 13, wherein the transceiver is a central office modem or a remote terminal modem.

17. An information storage media comprising instructions that when executed communicate diagnostic information over a communication channel using multicarrier modulation comprising:

instructions that when executed direct a transceiver to receive or transmit an initiate diagnostic mode message; and

instructions that when executed transmit a diagnostic message from the transceiver using multicarrier modulation, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and each bit in the diagnostic message is mapped to at least one DMT symbol, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

18. The media of claim 17, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

19. The media of claim 17, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

20. In a multicarrier modulation transceiver, a method of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

transmitting or receiving at the multicarrier modulation transceiver an initiate diagnostic mode message; and

transmitting from the multicarrier modulation transceiver a diagnostic message using multicarrier modulation with DMT symbols that are mapped to one bit of the diagnostic message, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

21. The method of claim **20**, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

22. The method of claim **20**, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

23. The method of claim **20**, wherein the transceiver is a central office modem or a remote terminal modem.

24. A diagnostic system capable of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

a transceiver capable of transmitting or receiving an initiate diagnostic mode message; and

a message determination module capable of determining and, in cooperation with the transceiver, transmitting from the transceiver a diagnostic message using multicarrier modulation with DMT symbols that are mapped to one bit of the diagnostic message, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

25. The system of claim **24**, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

26. The system of claim **24**, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

27. The system of claim **24**, wherein the transceiver is a central office modem or a remote terminal modem.

28. A multicarrier communication transceiver capable of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

means for transmitting or receiving at the multicarrier communication transceiver an initiate diagnostic mode message; and

means for transmitting from the multicarrier communication transceiver a diagnostic message using multicarrier modulation with DMT symbols that are mapped to one

bit of the diagnostic message, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

29. The transceiver of claim **28**, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

30. The transceiver of claim **28**, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

31. The transceiver of claim **28**, wherein the transceiver is a central office modem or a remote terminal modem.

32. In a multicarrier communication transceiver, a protocol for communicating diagnostic information over a communication channel using multicarrier modulation comprising:

transmitting or receiving at the multicarrier communication transceiver an initiate diagnostic mode message; and

transmitting from the multicarrier communication transceiver a diagnostic message using multicarrier modulation with DMT symbols that are mapped to one bit of the diagnostic message, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel, and wherein one variable comprises an array representing frequency domain received idle channel noise information.

33. The protocol of claim **32**, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

34. The protocol of claim **32**, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

35. The protocol of claim **32**, wherein the transceiver is a central office modem or a remote terminal modem.

36. An information storage media comprising instructions that when executed communicate diagnostic information over a communication channel using multicarrier modulation comprising:

instructions that when executed direct a transceiver to receive or transmit an initiate diagnostic mode message; and

instructions that when executed transmit from the transceiver a diagnostic message using multicarrier modulation with DMT symbols that are mapped to one bit of the diagnostic message, wherein the diagnostic message comprises a plurality of data variables representing the

diagnostic information about the communication channel, and wherein one variable comprises an array representing is frequency domain received idle channel noise information.

37. The media of claim **36**, wherein the initiate diagnostic mode message is based on at least one of an initialization failure, a bit rate failure, a CRC error in an initialization message, a CRC error during the normal steady state transmission mode, a forward error correction error, a user request and a CO technician request.

38. The media of claim **36**, wherein the diagnostic message comprises diagnostic information about the communication channel including at least one of a length of the diagnostic information, a time domain received reverb signal, a frequency domain reverb signal, an amplifier setting, a CO transmitter power spectral density, a frequency domain received idle channel, a signal to noise ratio, bits and gain information, and upstream and or downstream transmission rates.

39. In a multicarrier modulation transceiver, a method of communicating diagnostic information including a plurality of data variables over a communication channel using multicarrier modulation comprising:

associating, at said transceiver in a diagnostic message and based on an initiate diagnostic mode message, each bit in the diagnostic message with at least one DMT symbol, wherein one variable comprises an array representing frequency domain received idle channel noise information.

40. In a multicarrier modulation transceiver, a method of communicating diagnostic information over a communication channel using multicarrier modulation comprising:

transmitting, during a diagnostic mode, a diagnostic message using multicarrier modulation, wherein the diagnostic message comprises a plurality of data variables representing the diagnostic information about the communication channel and at least one bit in the diagnostic message is mapped to at least one DMT symbol, wherein one variable comprises an array representing frequency domain received idle channel noise information.

41. Communicating diagnostic information over a communication channel using multicarrier modulation comprising:

communicating from a transceiver a diagnostic message comprising a plurality of data variables representing the diagnostic information, wherein each bit in the diagnostic message is mapped to at least one DMT symbol, wherein one variable comprises an array representing frequency domain received idle channel noise information.

* * * * *

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(12) **United States Patent**
Tzannes

(10) **Patent No.: US 8,090,008 B2**
(45) **Date of Patent: *Jan. 3, 2012**

(54) **SYSTEM AND METHOD FOR SCRAMBLING THE PHASE OF THE CARRIERS IN A MULTICARRIER COMMUNICATIONS SYSTEM**

(75) Inventor: **Marcos C. Tzannes**, Orinda, CA (US)

(73) Assignee: **Aware, Inc.**, Bedford, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 106 days.

This patent is subject to a terminal disclaimer.

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(63) Continuation of application No. 12/255,713, filed on Oct. 22, 2008, now Pat. No. 7,769,104, which is a continuation of application No. 11/863,581, filed on Sep. 28, 2007, now Pat. No. 7,471,721, which is a continuation of application No. 11/211,535, filed on Aug. 26, 2005, now Pat. No. 7,292,627, which is a continuation of application No. 09/710,310, filed on Nov. 9, 2000, now Pat. No. 6,961,369.

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(51) **Int. Cl.**

H04B 1/38 (2006.01)
H04L 5/12 (2006.01)
H04L 27/36 (2006.01)

(52) **U.S. Cl.** **375/222**; 375/261; 375/298

(58) **Field of Classification Search** 375/219–220, 375/222, 259–262, 267, 295, 298–299, 320, 375/324, 340; 370/281, 295, 330, 343, 436, 370/478, 480–481; 455/73, 91, 108

See application file for complete search history.

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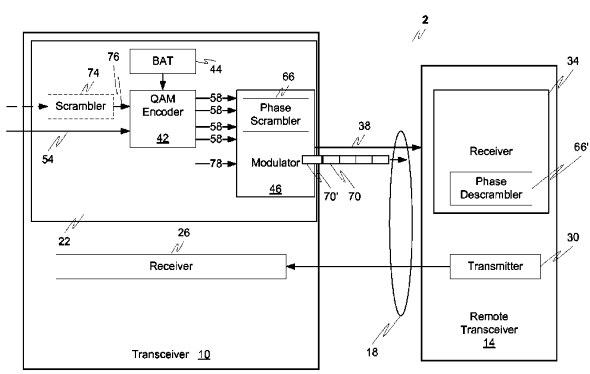
Primary Examiner — Tesfaldet Bocure
Assistant Examiner — Lawerence Williams
(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross PC

(57) **ABSTRACT**

A system and method that scrambles the phase characteristic of a carrier signal are described. The scrambling of the phase characteristic of each carrier signal includes associating a value with each carrier signal and computing a phase shift for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal so as to substantially scramble the phase characteristic of the carrier signals. Bits of an input signal are modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced PAR.

26 Claims, 2 Drawing Sheets



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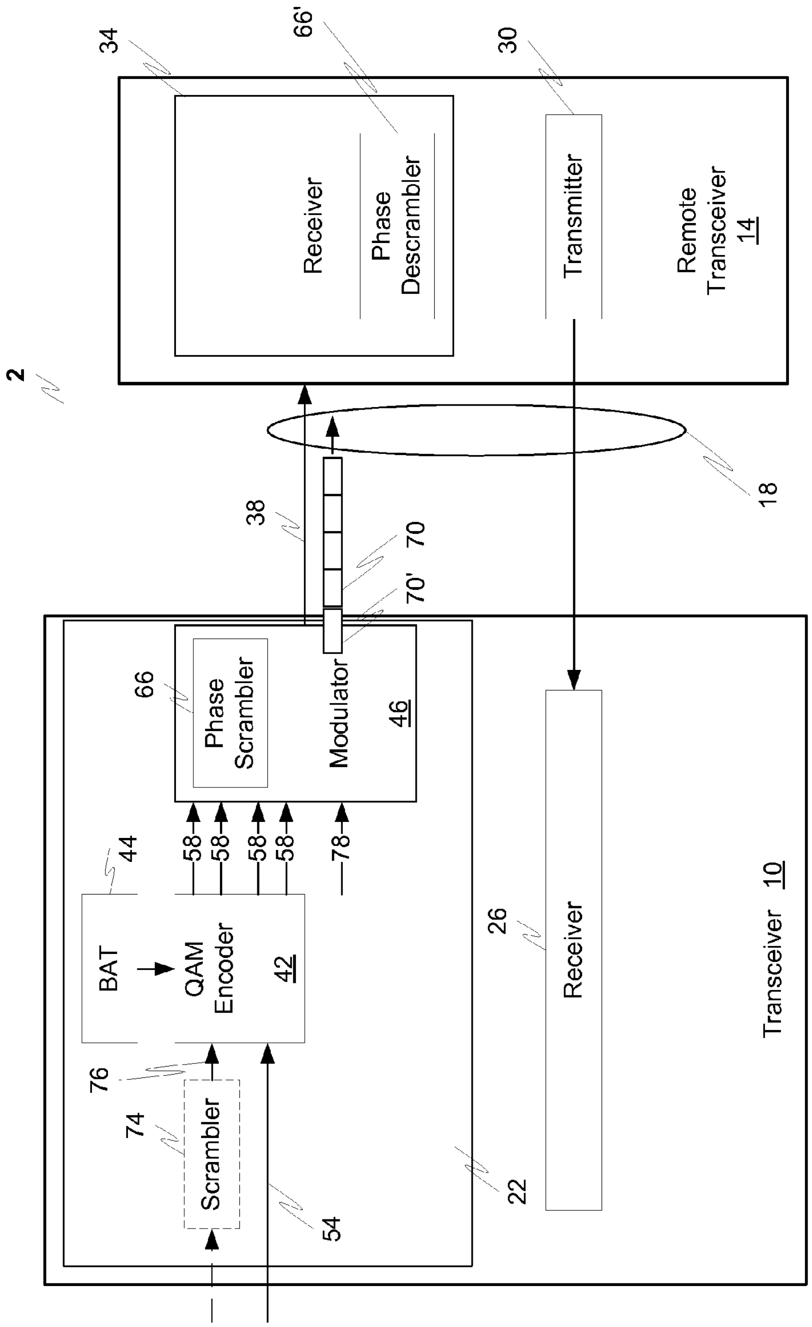
2
Receiver
Phase Descrambler
Transmitter
Remote Transceiver 14
34
66'
30
38
70
70'
18
Phase Scrambler
Modulator
46
66
BAT
QAM Encoder
42
44
58
78
76
74
Scrambler
54
22
26
Receiver
Transceiver 10

FIG. 1

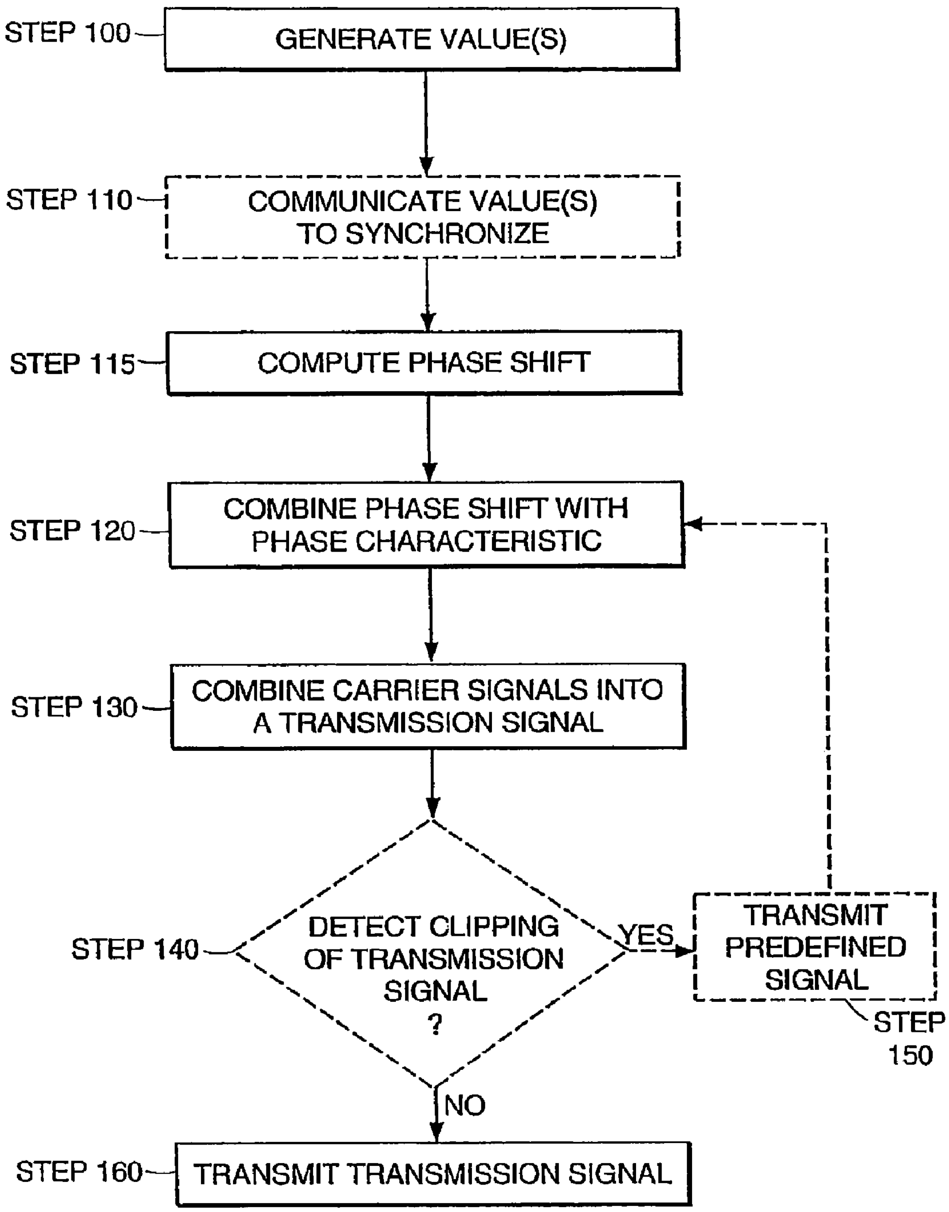
STEP 100
GENERATE VALUE(S)
STEP 110
COMMUNICATE VALUE(S) TO SYNCHRONIZE
STEP 115
COMPUTE PHASE SHIFT
STEP 120
COMBINE PHASE SHIFT WITH PHASE CHARACTERISTIC
STEP 130
COMBINE CARRIER SIGNALS INTO A TRANSMISSION SIGNAL
STEP 140
DETECT CLIPPING OF TRANSMISSION SIGNAL ?
YES
TRANSMIT PREDEFINED SIGNAL
STEP 150
NO
STEP 160
TRANSMIT TRANSMISSION SIGNAL

FIG. 2

SYSTEM AND METHOD FOR SCRAMBLING THE PHASE OF THE CARRIERS IN A MULTICARRIER COMMUNICATIONS SYSTEM

RELATED APPLICATION

This application is a Continuation of U.S. patent application Ser. No. 12/255,713, filed Oct. 22, 2008, now U.S. Pat. No. 7,769,104, which is a Continuation of U.S. patent application Ser. No. 11/863,581, filed Sep. 28, 2007, now U.S. Pat. No. 7,471,721, which is a Continuation of U.S. application Ser. No. 11/211,535, filed Aug. 26, 2005, now U.S. Pat. No. 7,292,627, which is a Continuation of U.S. patent application Ser. No. 09/710,310, filed Nov. 9, 2000, now U.S. Pat. No. 6,961,369, which claims the benefit of the filing date of copending U.S. Provisional Application Ser. No. 60/164,134, filed Nov. 9, 1999, entitled "A Method For Randomizing The Phase Of The Carriers In A Multicarrier Communications System To Reduce The Peak To Average Power Ratio Of The Transmitted Signal," each of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

This invention relates to communications systems using multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.

BACKGROUND OF THE INVENTION

In a conventional multicarrier communications system, transmitters communicate over a communication channel using multicarrier modulation or Discrete Multitone Modulation (DMT). Carrier signals (carriers) or sub-channels spaced within a usable frequency band of the communication channel are modulated at a symbol (i.e., block) transmission rate of the system. An input signal, which includes input data bits, is sent to a DMT transmitter, such as a DMT modem. The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals using an Inverse Fast Fourier Transform (IFFT) to generate a time domain signal, or transmission signal, that represents the input signal. The DMT transmitter transmits the transmission signal, which is a linear combination of the multiple carriers, to a DMT receiver over the communication channel.

The phase and amplitude of the carrier signals of DMT transmission signal can be considered random because the phase and amplitude result from the modulation of an arbitrary sequence of input data bits comprising the transmitted information. Therefore, under the condition that the modulated data bit stream is random, the DMT transmission signal can be approximated as having a Gaussian probability distribution. A bit scrambler is often used in the DMT transmitter to scramble the input data bits before the bits are modulated to assure that the transmitted data bits are random and, consequently, that the modulation of those bits produces a DMT transmission signal with a Gaussian probability distribution.

With an appropriate allocation of transmit power levels to the carriers or sub-channels, such a system provides a desirable performance. Further, generating a transmission signal with a Gaussian probability distribution is important in order to transmit a transmission signal with a low peak-to-average ratio (PAR), or peak-to-average power ratio. The PAR of a transmission signal is the ratio of the instantaneous peak value (i.e., maximum magnitude) of a signal parameter (e.g., voltage, current, phase, frequency, power) to the time-averaged value of the signal parameter. In DMT systems, the PAR of the transmitted signal is determined by the probability of the random transmission signal reaching a certain peak voltage during the time interval required for a certain number of symbols. An example of the PAR of a transmission signal transmitted from a DMT transmitter is 14.5 dB, which is equivalent to having a 1E-7 probability of clipping. The PAR of a transmission signal transmitted and received in a DMT communication system is an important consideration in the design of the DMT communication system because the PAR of a signal affects the communication system's total power consumption and component linearity requirements of the system.

If the phase of the modulated carriers is not random, then the PAR can increase greatly. Examples of cases where the phases of the modulated carrier signals are not random are when bit scramblers are not used, multiple carrier signals are used to modulate the same input data bits, and the constellation maps, which are mappings of input data bits to the phase of a carrier signal, used for modulation are not random enough (i.e., a zero value for a data bit corresponds to a 90 degree phase characteristic of the DMT carrier signal and a one value for a data bit corresponds to a −90 degree phase characteristic of the DMT carrier signal). An increased PAR can result in a system with high power consumption and/or with high probability of clipping the transmission signal. Thus, there remains a need for a system and method that can effectively scramble the phase of the modulated carrier signals in order to provide a low PAR for the transmission signal.

SUMMARY OF THE INVENTION

The present invention features a system and method that scrambles the phase characteristics of the modulated carrier signals in a transmission signal. In one aspect, a value is associated with each carrier signal. A phase shift is computed for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals.

In one embodiment, the input bit stream is modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced peak-to-average power ratio (PAR). The value is derived from a predetermined parameter, such as a random number generator, a carrier number, a DMT symbol count, a superframe count, and a hyperframe count. In another embodiment, a predetermined transmission signal is transmitted when the amplitude of the transmission signal exceeds a certain level.

In another aspect, the invention features a method wherein a value is associated with each carrier signal. The value is determined independently of any input bit value carried by that carrier signal. A phase shift for each carrier signal is computed based on the value associated with that carrier signal. The transmission signal is demodulated using the phase shift computed for each carrier signal.

In another aspect, the invention features a system comprising a phase scrambler that computes a phase shift for each carrier signal based on a value associated with that carrier signal. The phase scrambler also combines the phase shift computed for each carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristic of the carrier signals. In one embodiment, a modulator, in communication with the phase scrambler, modulates

bits of an input signal onto the carrier signals having the substantially scrambled phase characteristics to produce a transmission signal with a reduced PAR.

DESCRIPTION OF THE DRAWINGS

The invention is pointed out with particularity in the appended claims. The advantages of the invention described above, as well as further advantages of the invention, may be better understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a block diagram of an embodiment of a digital subscriber line communications system including a DMT (discrete multitone modulation) transceiver, in communication with a remote transceiver, having a phase scrambler for substantially scrambling the phase characteristics of carrier signals; and

FIG. **2** is a flow diagram of an embodiment of a process for scrambling the phase characteristics of the carrier signals in a transmission signal.

DETAILED DESCRIPTION

FIG. **1** shows a digital subscriber line (DSL) communication system **2** including a discrete multitone (DMT) transceiver **10** in communication with a remote transceiver **14** over a communication channel **18** using a transmission signal **38** having a plurality of carrier signals. The DMT transceiver **10** includes a DMT transmitter **22** and a DMT receiver **26**. The remote transceiver **14** includes a transmitter **30** and a receiver **34**. Although described with respect to discrete multitone modulation, the principles of the invention apply also to other types of multicarrier modulation, such as, but not limited to, orthogonally multiplexed quadrature amplitude modulation (OQAM), discrete wavelet multitone (DWMT) modulation, and orthogonal frequency division multiplexing (OFDM).

The communication channel **18** provides a downstream transmission path from the DMT transmitter **22** to the remote receiver **34**, and an upstream transmission path from the remote transmitter **30** to the DMT receiver **26**. In one embodiment, the communication channel **18** is a pair of twisted wires of a telephone subscriber line. In other embodiments, the communication channel **18** can be a fiber optic wire, a quad cable, consisting of two pairs of twisted wires, or a quad cable that is one of a star quad cable, a Dieselhorst-Martin quad cable, and the like. In a wireless communication system wherein the transceivers **10**, **14** are wireless modems, the communication channel **18** is the air through which the transmission signal **38** travels between the transceivers **10**, **14**.

By way of example, the DMT transmitter **22** shown in FIG. **1** includes a quadrature amplitude modulation (QAM) encoder **42**, a modulator **46**, a bit allocation table (BAT) **44**, and a phase scrambler **66**. The DMT transmitter **22** can also include a bit scrambler **74**, as described further below. The remote transmitter **30** of the remote transceiver **14** comprises equivalent components as the DMT transmitter **22**. Although this embodiment specifies a detailed description of the DMT transmitter **22**, the inventive concepts apply also to the receivers **34**, **24** which have similar components to that of the DMT transmitter **22**, but perform inverse functions in a reverse order.

The QAM encoder **42** has a single input for receiving an input serial data bit stream **54** and multiple parallel outputs to transmit QAM symbols **58** generated by the QAM encoder **42** from the bit stream **54**. In general, the QAM encoder **42** maps the input serial bit-stream **54** in the time domain into parallel QAM symbols **58** in the frequency domain. In particular, the QAM encoder **42** maps the input serial data bit stream **54** into N parallel quadrature amplitude modulation (QAM) constellation points **58**, or QAM symbols **58**, where N represents the number of carrier signals generated by the modulator **46**. The BAT **44** is in communication with the QAM encoder **42** to specify the number of bits carried by each carrier signal. The QAM symbols **58** represent the amplitude and the phase characteristic of each carrier signal.

The modulator **46** provides functionality associated with the DMT modulation and transforms the QAM symbols **58** into DMT symbols **70** each comprised of a plurality of time-domain samples. The modulator **46** modulates each carrier signal with a different QAM symbol **58**. As a result of this modulation, carrier signals have phase and amplitude characteristics based on the QAM symbol **58** and therefore based on the input-bit stream **54**. In particular, the modulator **46** uses an inverse fast Fourier transform (IFFT) to change the QAM symbols **58** into a transmission signal **38** comprised of a sequence of DMT symbols **70**. The modulator **46** changes the QAM symbols **58** into DMT symbols **70** through modulation of the carrier signals. In another embodiment, the modulator **46** uses the inverse discrete Fourier transform (IDFT) to change the QAM symbols **58** into DMT symbols **70**. In one embodiment, a pilot tone is included in the transmission signal **38** to provide a reference signal for coherent demodulation of the carrier signals in the remote receiver **34** during reception of the transmission signal **38**.

The modulator **46** also includes a phase scrambler **66** that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristic of that carrier signal. Combining phase shifts with phase characteristics, in accordance with the principles of the invention, substantially scrambles the phase characteristics of the carrier signals in the transmission signal **38**. By scrambling the phase characteristics of the carrier signals, the resulting transmission signal **38** has a substantially minimized peak-to-average (PAR) power ratio. The phase scrambler **66** can be part of or external to the modulator **46**. Other embodiments of the phase scrambler **66** include, but are not limited to, a software program that is stored in local memory and is executed on the modulator **46**, a digital signal processor (DSP) capable of performing mathematical functions and algorithms, and the like. The remote receiver **34** similarly includes a phase descrambler **66'** for use when demodulating carrier signals that have had their phase characteristics adjusted by the phase scrambler **66** of the DMT transceiver **10**.

To compute a phase shift for each carrier signal, the phase scrambler **66** associates one or more values with that carrier signal. The phase scrambler **66** determines each value for a carrier signal independently of the QAM symbols **58**, and, therefore, independently of the bit value(s) modulated onto the carrier signal. The actual value(s) that the phase scrambler **66** associates with each carrier signal can be derived from one or more predefined parameters, such as a pseudo-random number generator (pseudo-RNG), a DMT carrier number, a DMT symbol count, a DMT superframe count, a DMT hyperframe count, and the like, as described in more detail below. Irrespective of the technique used to produce each value, the same technique is used by the DMT transmitter **22** and the remote receiver **34** so that the value associated with a given carrier signal is known at both ends of the communication channel **18**.

The phase scrambler **66** then solves a predetermined equation to compute a phase shift for the carrier signal, using the value(s) associated with that carrier signal as input that effects the output of the equation. Any equation suitable for comput-

ing phase shifts can be used to compute the phase shifts. When the equation is independent of the bit values of the input serial bit stream **54**, the computed phase shifts are also independent of such bit values.

In one embodiment (shown in phantom), the DMT transmitter **22** includes a bit scrambler **74**, which receives the input serial bit stream **54** and outputs data bits **76** that are substantially scrambled. The substantially scrambled bits **76** are then passed to the QAM encoder **42**. When the bit scrambler **74** is included in the DMT transmitter **22**, the operation of the phase scrambler **66** further assures that the transmission signal **38** has a Gaussian probability distribution and, therefore, a substantially minimized PAR.

FIG. **2** shows embodiments of a process used by the DMT transmitter **22** for adjusting the phase characteristic of each carrier signal and combining these carrier signals to produce the transmission signal **38**. The DMT transmitter **22** generates (step **100**) a value that is associated with a carrier signal. Because the value is being used to alter the phase characteristics of the carrier signal, both the DMT transmitter **22** and the remote receiver **34** must recognize the value as being associated with the carrier signal. Either the DMT transmitter **22** and the remote receiver **34** independently derive the associated value, or one informs the other of the associated value. For example, in one embodiment the DMT transmitter **22** can derive the value from a pseudo-RNG and then transmit the generated value to the remote receiver **34**. In another embodiment, the remote receiver **34** similarly derives the value from the same pseudo-RNG and the same seed as used by the transmitter (i.e., the transmitter pseudo-RNG produces the same series of random numbers as the receiver pseudo-RNG).

As another example, the DMT transmitter **22** and the remote receiver **34** can each maintain a symbol counter for counting DMT symbols. The DMT transmitter **22** increments its symbol counter upon transmitting a DMT symbol; the remote receiver **34** upon receipt. Thus, when the DMT transmitter **22** and the remote receiver **34** both use the symbol count as a value for computing phase shifts, both the DMT transmitter **22** and remote receiver **34** "know" that the value is associated with a particular DMT symbol and with each carrier signal of that DMT symbol.

Values can also be derived from other types of predefined parameters. For example, if the predefined parameter is the DMT carrier number, then the value associated with a particular carrier signal is the carrier number of that signal within the DMT symbol. The number of a carrier signal represents the location of the frequency of the carrier signal relative to the frequency of other carrier signals within a DMT symbol. For example, in one embodiment the DSL communication system **2** provides 256 carrier signals, each separated by a frequency of 4.3125 kHz and spanning the frequency bandwidth from 0 kHz to 1104 kHz. The DMT transmitter **22** numbers the carrier signals from 0 to 255. Therefore, "DMT carrier number 50" represents the 51st DMT carrier signal which is located at the frequency of 215.625 kHz (i.e., 51×4.3125 kHz).

Again, the DMT transmitter **22** and the remote receiver **34** can know the value that is associated with the carrier signal because both the DMT transmitter **22** and the remote receiver **34** use the same predefined parameter (here, the DMT carrier number) to make the value-carrier signal association. In other embodiments (as exemplified above with the transmitter pseudo-RNG), the DMT transmitter **22** can transmit the value to the remote receiver **34** (or vice versa) over the communication channel **18**.

In other embodiments, other predefined parameters can be used in conjunction with the symbol count. One example of such a predefined parameter is the superframe count that increments by one every 69 DMT symbols. One exemplary implementation that achieves the superframe counter is to perform a modulo 68 operation on the symbol count. As another example, the DMT transmitter **22** can maintain a hyperframe counter for counting hyperframes. An exemplary implementation of the hyperframe count is to perform a modulo 255 operation on the superframe count. Thus, the hyperframe count increments by one each time the superframe count reaches 255.

Accordingly, it is seen that some predefined parameters produce values that vary from carrier signal to carrier signal. For example, when the predefined parameter is the DMT carrier number, values vary based on the frequency of the carrier signal. As another example, the pseudo-RNG generates a new random value for each carrier signal.

Other predefined parameters produce values that vary from DMT symbol **70** to DMT symbol **70**. For example, when the predefined parameter is the symbol count, the superframe count, or hyperframe count, values vary based on the numerical position of the DMT symbol **70** within a sequence of symbols, superframes, or hyperframes. Predefined parameters such as the pseudo-RNG, symbol count, superframe count, and superframe can also be understood to be parameters that vary values over time. Any one or combination of the predefined parameters can provide values for input to the equation that computes a phase shift for a given carrier signal.

In one embodiment, the phase scrambling is used to avoid clipping of the transmission signal **38** on a DMT symbol **70** by DMT symbol **70** basis. In this embodiment, the DMT transmitter **22** uses a value based on a predefined parameter that varies over time, such as the symbol count, to compute the phase shift. It is to be understood that other types of predefined parameters that vary the values associated with carrier signals can be used to practice the principles of the invention. As described above, the transceivers **10**, **14** may communicate (step **110**) the values to synchronize their use in modulating and demodulating the carrier signals.

The DMT transmitter **22** then computes (step **115**) the phase shift that is used to adjust the phase characteristic of each carrier signal. The amount of the phase shift combined with the phase characteristic of each QAM-modulated carrier signal depends upon the equation used and the one or more values associated with that carrier signal.

The DMT transmitter **22** then combines (step **120**) the phase shift computed for each carrier signal with the phase characteristic of that carrier signal. By scrambling the phase characteristics of the carrier signals, the phase scrambler **66** reduces (with respect to unscrambled phase characteristics) the combined PAR of the plurality of carrier signals and, consequently, the transmission signal **38**. The following three phase shifting examples, PS #1-PS #3, illustrate methods used by the phase scrambler **66** to combine a computed phase shift to the phase characteristic of each carrier signal.

Phase Shifting Example #1

Phase shifting example #1 (PS #1) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$N \times \frac{\pi}{3},$$

modulo (mod) 2π. In this example, a carrier signal having a carrier number N equal to 50 has a phase shift added to the phase characteristic of that carrier signal equal to

$$50 \times \frac{\pi}{3}(\text{mod}2\pi) = \frac{2}{3}\pi.$$

The carrier signal with a carrier number N equal to 51 has a phase shift added to the phase characteristic of that carrier signal equal to

$$51 \times \frac{\pi}{3}(\text{mod}2\pi) = \pi.$$

The carrier signal with the carrier number N equal to 0 has no phase shift added to the phase characteristic of that carrier signal.

Phase Shifting Example #2

Phase shifting example #2 (PS #2) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$(N + M) \times \frac{\pi}{4},$$

mod 2π, where M is the symbol count. In this example, a carrier signal having a carrier number N equal to 50 on DMT symbol count M equal to 8 has a phase shift added to the phase characteristic of that carrier signal equal to

$$(50 + 8) \times \frac{\pi}{4}(\text{mod}2\pi) = \frac{\pi}{2}.$$

The carrier signal with the same carrier number N equal to 50 on the next DMT symbol count M equal to 9 has a phase shift added to the phase characteristic of that carrier signal equal to

$$(50 + 9) \times \frac{\pi}{4}(\text{mod}2\pi) = \frac{3\pi}{4}.$$

Phase Shifting Example #3

Phase shifting example #3 (PS #3) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$(X_N) \times \frac{\pi}{6},$$

mod 2π, where X_N is an array of N pseudo-random numbers. In this example, a carrier signal having a carrier number N equal to 5 and X_N equal to [3, 8, 1, 4, 9, 5, . . .] has a phase shift added to the phase characteristic of the carrier signal that is equal to

$$(9) \times \frac{\pi}{6}(\text{mod}2\pi) = \frac{3\pi}{2}$$

(Note that 9 is the 5^{th} value in X_N.) The carrier signal with a carrier number N equal to 6 has a phase shift added to the phase characteristic of the carrier signal equal to

$$(5) \times \frac{\pi}{6}(\text{mod}2\pi) = \frac{5\pi}{6}.$$

It is to be understood that additional and/or different phase shifting techniques can be used by the phase scrambler **66**, and that PS #1, #2, and #3 are merely illustrative examples of the principles of the invention. The DMT transmitter **22** then combines (step **130**) the carrier signals to form the transmission signal **38**. If the transmission signal is not clipped, as described below, the DMT transmitter **22** consequently transmits (step **160**) the transmission signal **38** to the remote receiver **34**.

Clipping of Transmission Signals

A transmission signal **38** that has high peak values of voltage (i.e., a high PAR) can induce non-linear distortion in the DMT transmitter **22** and the communication channel **18**. One form of this non-linear distortion of the transmission signal **38** that may occur is the limitation of the amplitude of the transmission signal **38** (i.e., clipping). For example, a particular DMT symbol **70** clips in the time domain when one or more time domain samples in that DMT symbol **70** are larger than the maximum allowed digital value for the DMT symbols **70**. In multicarrier communication systems when clipping occurs, the transmission signal **38** does not accurately represent the input serial data bit signal **54**.

In one embodiment, the DSL communication system **2** avoids the clipping of the transmission signal **38** on a DMT symbol **70** by DMT symbol **70** basis. The DMT transmitter **22** detects (step **140**) the clipping of the transmission signal **38**. If a particular DMT symbol **70** clips in the time domain to produce a clipped transmission signal **38**, the DMT transmitter **22** substitutes (step **150**) a predefined transmission signal **78** for the clipped transmission signal **38**.

The predefined transmission signal **78** has the same duration as a DMT symbol **70** (e.g., 250 ms) in order to maintain symbol timing between the DMT transmitter **22** and the remote receiver **34**. The predefined transmission signal **78** is not based on (i.e., independent of) the modulated input data bit stream **54**; it is a bit value pattern that is recognized by the remote receiver **34** as a substituted signal. In one embodiment, the predefined transmission signal **78** is a known pseudo-random sequence pattern that is easily detected by the remote receiver **34**. In another embodiment, the predefined transmission signal **78** is an "all zeros" signal, which is a zero voltage signal produced at the DMT transmitter **22** output (i.e., zero volts modulated on all the carrier signals). In addition to easy detection by the remote receiver **34**, the zero voltage signal reduces the power consumption of the DMT transmitter **22** when delivered by the DMT transmitter **22**. Further, a pilot tone is included in the predefined transmission signal **78** to provide a reference signal for coherent demodulation of the carrier signals in the remote receiver **34** during reception of the predefined transmission signal **78**.

After the remote receiver **34** receives the transmission signal **38**, the remote receiver **34** determines if the transmission signal **38** is equivalent to the predefined transmission signal **78**. In one embodiment, when the remote receiver **34** identi-

fies the predefined transmission signal **78**, the remote receiver **34** ignores (i.e., discards) the predefined transmission signal **78**.

Following the transmission of the predefined transmission signal **78**, the phase scrambler **66** shifts (step **120**) the phase characteristic of the QAM-modulated carrier signals (based on one of the predefined parameters that varies over time). For example, consider that a set of QAM symbols **58** produces a DMT symbol **70** comprising a plurality of time domain samples, and that one of the time domain samples is larger than the maximum allowed digital value for the DMT symbol **70**. Therefore, because the transmission signal **38** would be clipped when sent to the remote receiver **34**, the DMT transmitter **22** sends the predefined transmission signal **78** instead.

After transmission of the predefined transmission signal **78**, the DMT transmitter **22** again attempts to send the same bit values that produced the clipped transmission signal **38** in a subsequent DMT symbol **70'**. Because the generation of phase shifts in this embodiment is based on values that vary over time, the phase shifts computed for the subsequent DMT symbol **70'** are different than those that were previously computed for the DMT symbol **70** with the clipped time domain sample. These different phase shifts are combined to the phase characteristics of the modulated carrier signals to produce carrier signals of the subsequent DMT symbol **70'** with different phase characteristics than the carrier signals of the DMT symbol **70** with the clipped time domain sample.

DMT communication systems **2** infrequently produce transmission signals **38** that clip (e.g., approximately one clip every 10^7 time domain samples **70**). However, if the subsequent DMT symbol **70'** includes a time domain sample that clips, then the predefined transmission signal **78** is again transmitted (step **150**) to the remote receiver **34** instead of the clipped transmission signal **38**. The clipping time domain sample may be on the same or on a different carrier signal than the previously clipped DMT symbol **70**. The DMT transmitter **22** repeats the transmission of the predefined transmission signal **78** until the DMT transmitter **22** produces a subsequent DMT symbol **70'** that is not clipped. When the DMT transmitter **22** produces a DMT symbol **70'** that is not clipped, the DTM transmitter **22** transmits (step **160**) the transmission signal **38** to the remote receiver **34**. The probability of a DMT symbol **70** producing a transmission signal **38** that clips in the time domain depends on the PAR of the transmission signal **38**.

For example, the following phase shifting example, PST #4, illustrates the method used by the phase scrambler **66** to combine a different phase shift to the phase characteristic of each carrier signal to avoid the clipping of the transmission signal **38**.

Phase Shifting Example #4

Phase shifting example #4 (PS #4) corresponds to adjusting the phase characteristic of the carrier signal associated with a carrier number N by

$$\frac{\pi}{3} \times (M + N),$$

mod 2π, where M is the DMT symbol count. In this example, if the DMT symbol **70** clips when the DMT symbol count M equals 5, the predefined transmission signal **78** is transmitted instead of the current clipped transmission signal **38**. On the following DMT symbol period, the DMT count M equals 6, thereby causing a different set of time domain samples to be generated for the subsequent DMT symbol **70'**, although the QAM symbols **58** used to produce both DMT symbols **70**, **70'** are the same.

If this different set of time domain samples (and consequently the transmission signal **38**) is not clipped, the DMT transmitter **22** sends the transmission signal **38**. If one of the time domain samples in the different set of time domain samples **70** (and consequently the transmission signal **38**) is clipped, then the DMT transmitter **22** sends the predefined transmission signal **78** again. The process continues until a DMT symbol **70** is produced without a time domain sample **70** that is clipped. In one embodiment, the transmitter **22** stops attempting to produce a non-clipped DMT symbol **70'** for the particular set of QAM symbols **58** after generating a predetermined number of clipped DMT symbols **70'**. At that moment, the transmitter **22** can transmit the most recently produced clipped DMT symbol **70'** or the predetermined transmission signal **78**.

The PAR of the DSL communication system **2** is reduced because the predefined transmission signal **78** is sent instead of the transmission signal **38** when the DMT symbol **70** clips. For example, a DMT communication system **2** that normally has a clipping probability of 10-7 for the time domain transmission signal **38** can therefore operate with a 10-5 probability of clipping and a lower PAR equal to 12.8 dB (as compared to 14.5 dB). When operating at a 10-5 probability of clipping, assuming a DMT symbol **70** has 512 time-domain samples **70**, the DMT transmitter **22** experiences one clipped DMT symbol **70** out of every

$$\frac{10^5}{512},$$

or 195 DMT symbols **70**. This results in the predefined (non-data carrying) transmission signal **78** being transmitted, on average, once every 195 DMT symbols. Although increasing the probability of clipping to 10^{-5} results in approximately a 0.5% (1/195) decrease in throughput, the PAR of the transmission signal **38** is reduced by 1.7 dB, which reduces transmitter complexity in the form of power consumption and component linearity.

While the invention has been shown and described with reference to specific preferred embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the following claims. For example, although the specification uses DSL to describe the invention, it is to be understood that various form of DSL can be used, e.g., ADSL, VDSL, SDSL, HDSL, HDSL2, or SHDSL. It is also to be understood that the principles of the invention apply to various types of applications transported over DSL systems (e.g., telecommuting, video conferencing, high speed Internet access, video-on demand).

What is claimed is:

1. A method for scrambling phase characteristics of carrier signals in a first multicarrier transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the method comprising:

associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-

random number generator; computing a phase shift for each carrier signal based on the value associated with that carrier signal; and

combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal so as to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first multicarrier transceiver to modulate the same bit value.

2. The method of claim **1**, wherein the first transceiver is a cable transceiver.

3. The method of claim **1**, wherein the first transceiver is a VDSL transceiver.

4. The method of claim **1**, wherein the bit stream is used to transport video.

5. The method of claim **1**, wherein the bit stream is used to transport high speed internet access.

6. The method of claim **1**, further comprising, in a second transceiver in communication with the first transceiver, independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver.

7. The method of claim **6**, wherein the first and second transceivers use a same seed for the pseudo-random number generator.

8. The method of claim **6**, wherein the first and second transceivers are wireless transceivers.

9. The method of claim **6**, wherein the first and second transceivers are cable transceivers.

10. The method of claim **6**, wherein the first and second transceivers are DSL transceivers connected using a pair of twisted wires of a telephone subscriber system.

11. The method of claim **10**, wherein the first and second transceivers are VDSL transceivers.

12. The method of claim **6**, wherein the bit stream is used to transport video.

13. The method of claim **6**, wherein the bit stream is used to transport high speed internet access.

14. A multicarrier system including a first transceiver that uses a plurality of carrier signals for modulating a bit stream, wherein each carrier signal has a phase characteristic associated with the bit stream, the transceiver capable of:

associating each carrier signal with a value determined independently of any bit value of the bit stream carried by that respective carrier signal, the value associated with each carrier signal determined using a pseudo-random number generator;

computing a phase shift for each carrier signal based on the value associated with that carrier signal; and

combining the phase shift computed for each respective carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the plurality of carrier signals, wherein multiple carrier signals corresponding to the scrambled carrier signals are used by the first transceiver to modulate the same bit value.

15. The system of claim **14**, wherein the first transceiver is a cable transceiver.

16. The system of claim **14**, wherein the first transceiver is a VDSL transceiver.

17. The system of claim **14**, wherein the bit stream is used to transport video.

18. The system of claim **14**, wherein the bit stream is used to transport high speed internet access.

19. The system of claim **14**, further comprising a second transceiver in communication with the first transceiver, the second transceiver independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver.

20. The system of claim **19**, wherein the first and second transceivers use a same seed for the pseudo-random number generator.

21. The system of claim **19**, wherein the first and second transceivers are wireless transceivers.

22. The system of claim **19**, wherein the first and second transceivers are cable transceivers.

23. The system of claim **19**, wherein the first and second transceivers are DSL transceivers connected using a pair of twisted wires of a telephone subscriber system.

24. The system of claim **23**, wherein the first and second transceivers are VDSL transceivers.

25. The system of claim **19**, wherein the bit stream is used to transport video.

26. The system of claim **19**, wherein the bit stream is used to transport high speed internet access.

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(12) **United States Patent**
Tzannes et al.

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(54) **RESOURCE SHARING IN A TELECOMMUNICATIONS ENVIRONMENT**

(75) Inventors: **Marcos C. Tzannes**, Orinda, CA (US); **Michael Lund**, West Newton, MA (US)

(73) Assignee: **Aware, Inc.**, Bedford, MA (US)

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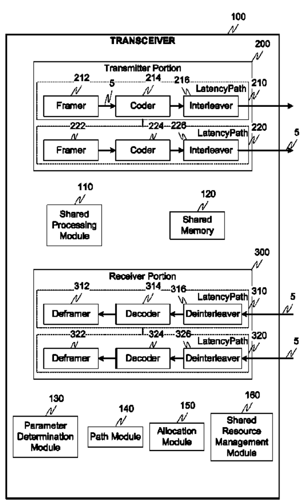
Primary Examiner — John J Tabone, Jr.

(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross, PC

(57) **ABSTRACT**

A system allocates shared memory by transmitting/receiving a message specifying a maximum number of bytes of memory that are available to be allocated to an interleaver. The system determines an amount of memory required by the interleaver to interleave a first plurality of RS coded data bytes within a shared memory and allocates a first number of bytes of the shared memory to the interleaver to interleave the first plurality of RS coded data bytes for transmission at a first data rate. The system also allocates a second number of bytes of the shared memory to a deinterleaver to deinterleave a second plurality of RS coded data bytes received at a second data rate and interleaves the first plurality of RS coded data bytes within the shared memory allocated to the interleaver and deinterleaves the second plurality of RS coded data bytes within the shared memory allocated to the deinterleaver.

8 Claims, 3 Drawing Sheets



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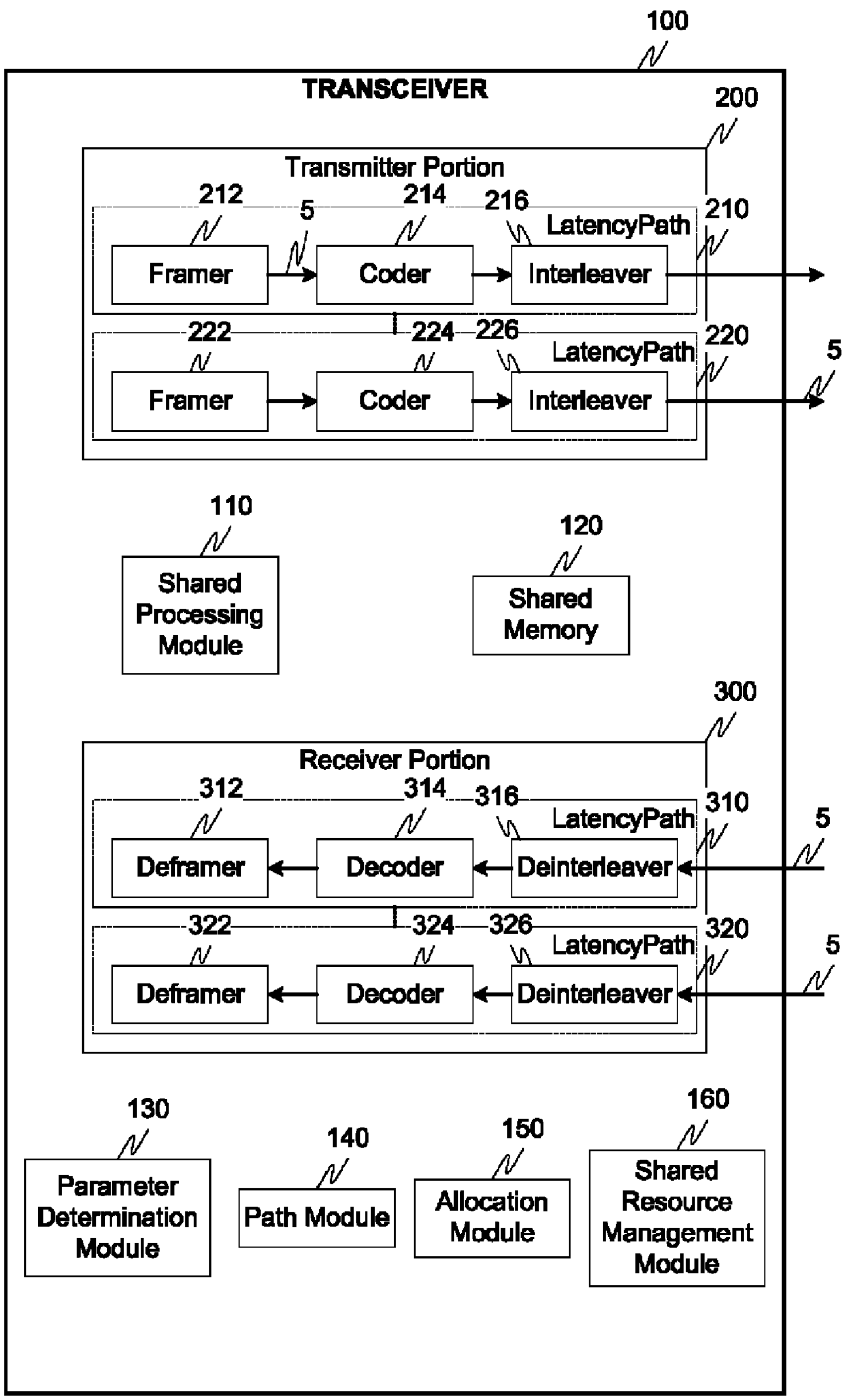
100
TRANSCEIVER
200
Transmitter Portion
212
5
214
216
LatencyPath
210
Framer
Coder
Interleaver
222
224
226
LatencyPath
220
5
Framer
Coder
Interleaver
110
Shared Processing Module
120
Shared Memory
300
Receiver Portion
312
314
316
LatencyPath
310
5
Deframer
Decoder
Deinterleaver
322
324
326
LatencyPath
320
5
Deframer
Decoder
Deinterleaver
130
Parameter Determination Module
140
Path Module
150
Allocation Module
160
Shared Resource Management Module

Fig. 1

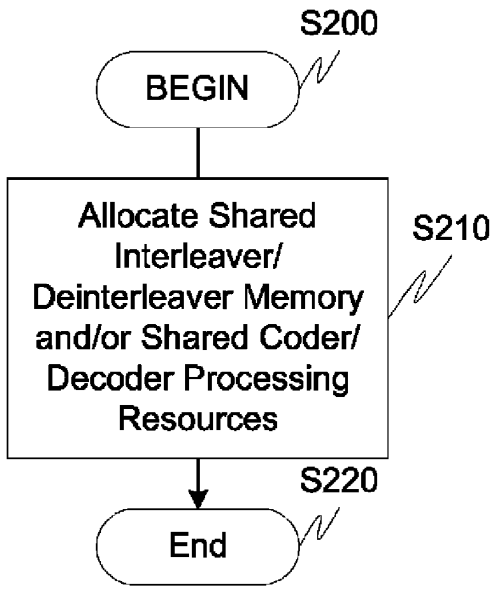
S200
BEGIN
Allocate Shared Interleaver/ Deinterleaver Memory and/or Shared Coder/ Decoder Processing Resources
S210
S220
End

Fig. 2

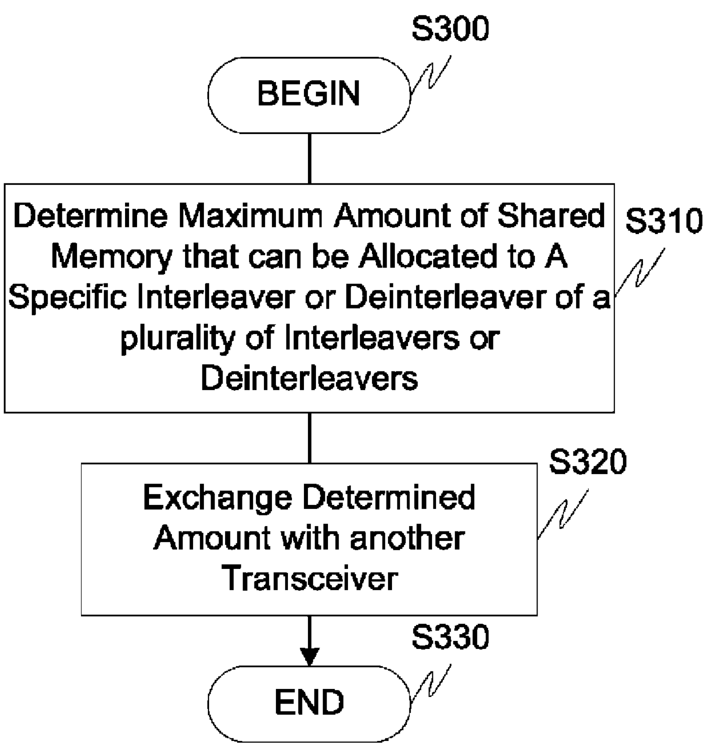
S300
BEGIN
Determine Maximum Amount of Shared Memory that can be Allocated to A Specific Interleaver or Deinterleaver of a plurality of Interleavers or Deinterleavers
S310
Exchange Determined Amount with another Transceiver
S320
S330
END

Fig. 3

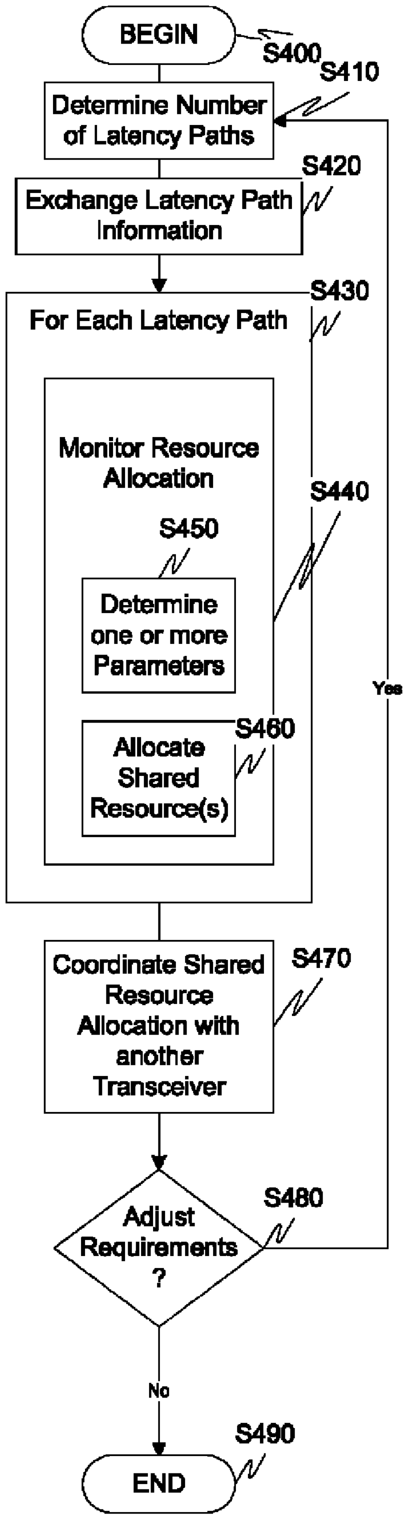

Fig. 4

TQD_TX-00043914

RESOURCE SHARING IN A TELECOMMUNICATIONS ENVIRONMENT

RELATED APPLICATION DATA

This application is a Continuation of U.S. application Ser. No. 12/761,586, filed Apr. 16, 2010, now U.S. Pat. No. 7,844, 882, which is a Continuation of U.S. application Ser. No. 11/246,163 filed Oct. 11, 2005, now U.S. Pat. No. 7,831,890, which claims the benefit of and priority under 35 U.S.C. §119(e) to U.S. Patent Application No. 60/618,269, filed Oct. 12, 2004, entitled "Sharing Memory and Processing Resources in DSL Systems," each of which are incorporated herein by reference in their entirety.

BACKGROUND

1. Field of the Invention

This invention generally relates to communication systems. More specifically, an exemplary embodiment of this invention relates to memory sharing in communication systems. Another exemplary embodiment relates to processing or coding resource sharing in a communication system.

2. Description of Related Art

U.S. Pat. Nos. 6,775,320 and 6,778,596 describe DSL systems supporting multiple applications and multiple framer/coder/interleaver FCI blocks (an FCI block is also referred to as a latency path). DSL systems carry applications that have different transmission requirements with regard to, for example, data rate, latency (delay), bit error rate (BER), and the like. For example, video typically requires a low BER (<1E-10) but can tolerate higher latency (>20 ms). Voice, on the other hand, typically requires a low latency (<1 ms) but can tolerate BER (>1E-3).

As described in U.S. Pat. No. 6,775,320, different applications can use different latency paths in order to satisfy the different application requirements of the communication system. As a result a transceiver must support multiple latency paths in order to support applications such as video, Internet access and voice telephony. When implemented in a transceiver, each of the latency paths will have a framer, coder, and interleaver block with different capabilities that depend on the application requirements.

SUMMARY

One difficulty with implementing multiple latency paths in a transceiver is the fact that a latency path is a complicated digital circuit that requires a large amount of memory and processing power. An interleaver within a latency path can consume a large amount of memory in order to provide error correcting capability. For example, a typical DSL transceiver will have at least one latency path with approximately 16 kbytes of memory for the interleaver. Likewise, the coding block, for example, a Reed Solomon coder, consumes a large amount of processing power. In general, as the number of latency paths increase, the memory and processing power requirements for a communication system become larger.

Accordingly, an exemplary aspect of this invention relates to sharing memory between one or more interleavers and/or deinterleavers in a transceiver. More particularly, an exemplary aspect of this invention relates to shared latency path memory in a transceiver.

Additional aspects of this invention relate to configuring and initializing shared memory in a communication system. More particularly, an exemplary aspect of this invention

relates to configuring and initializing interleaver/deinterleaver memory in a communication system.

Additional aspects of the invention relate to determining the amount of memory that can be allocated to a particular component by a communication system. More specifically, an exemplary aspect of the invention relates to determining the maximum amount of shared memory that can be allocated to one or more interleaves or deinterleavers.

According to another exemplary aspect of the invention, processing power is shared between a number of transceiver modules. More specifically, and in accordance with an exemplary embodiment of the invention, a coding module is shared between one or more coders and/or decoders.

Another exemplary embodiment of the invention relates to transitioning from a fixed memory configuration to a shared memory configuration during one or more of initialization and SHOWTIME (user data transmission).

An additional exemplary aspect of the invention relates to dynamically updating one or more of shared memory and processing resources based on changing communication conditions.

An additional exemplary aspect of the invention relates to updating one or more of shared memory and processing resources based on an updated communication parameter.

An additional exemplary aspect of the invention relates to updating the allocation of one or more of shared memory and processing resources based on an updated communication parameter(s).

Additional aspects of the invention relate to exchanging shared resource allocations between transceivers.

Additional exemplary aspects relate to a method of allocating shared memory in a transceiver comprising allocating the shared memory to a plurality of modules, wherein each of the plurality of modules comprise at least one interleaver, at least one deinterleaver or a combination thereof.

Still further aspects relate to the above method wherein the plurality of modules comprise interleavers.

Still further aspects relate to the above method wherein the plurality of modules comprise deinterleavers.

Still further aspects relate to the above method wherein the plurality of modules comprise at least one interleaver and at least one deinterleaver.

Additional exemplary aspects relate to a transceiver comprising a plurality of modules each including at least one interleaver, at least one deinterleaver or a combination thereof and a shared memory designed to be allocated to a plurality of the modules.

Still further aspects relate to the above transceiver wherein the plurality of modules comprise interleavers.

Still further aspects relate to the above transceiver wherein the plurality of modules comprise deinterleavers.

Still further aspects relate to the above transceiver wherein the plurality of modules comprise at least one interleaver and at least one deinterleaver.

These and other features and advantages of this invention are described in, or are apparent from, the following description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the invention will be described in detail, with reference to the following figures, wherein:

FIG. **1** is a functional block diagram illustrating an exemplary transceiver according to this invention;

FIG. **2** is a flowchart outlining an exemplary method of sharing resources according to this invention;

FIG. **3** is a flowchart outlining an exemplary method of determining a maximum amount of shared memory according to this invention; and

FIG. **4** is a flowchart outlining an exemplary resource sharing methodology according to this invention.

DETAILED DESCRIPTION

The exemplary embodiments of this invention will be described in relation to sharing resources in a wired and/or wireless communications environment. However, it should be appreciated, that in general, the systems and methods of this invention will work equally well for any type of communication system in any environment.

The exemplary systems and methods of this invention will also be described in relation to multicarrier modems, such as DSL modems and VDSL modems, and associated communication hardware, software and communication channels. However, to avoid unnecessarily obscuring the present invention, the following description omits well-known structures and devices that may be shown in block diagram form or otherwise summarized.

For purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the present invention. It should be appreciated however that the present invention may be practiced in a variety of ways beyond the specific details set forth herein.

Furthermore, while the exemplary embodiments illustrated herein show the various components of the system collocated, it is to be appreciated that the various components of the system can be located at distant portions of a distributed network, such as a telecommunications network and/or the Internet, or within a dedicated secure, unsecured and/or encrypted system. Thus, it should be appreciated that the components of the system can be combined into one or more devices, such as a modem, or collocated on a particular node of a distributed network, such as a telecommunications network. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the system can be arranged at any location within a distributed network without affecting the operation of the system. For example, the various components can be located in a Central Office modem (CO, ATU-C, VTU-O), a Customer Premises modem (CPE, ATU-R, VTU-R), a DSL management device, or some combination thereof. Similarly, one or more functional portions of the system could be distributed between a modem and an associated computing device.

Furthermore, it should be appreciated that the various links, including communications channel **5**, connecting the elements can be wired or wireless links, or any combination thereof, or any other known or later developed element(s) that is capable of supplying and/or communicating data to and from the connected elements. The term module as used herein can refer to any known or later developed hardware, software, firmware, or combination thereof that is capable of performing the functionality associated with that element. The terms determine, calculate and compute, and variations thereof, as used herein are used interchangeably and include any type of methodology, process, mathematical operation or technique. FCI block and latency path are used interchangeably herein as well as transmitting modem and transmitting transceiver. Receiving modem and receiving transceiver are also used interchangeably.

FIG. **1** illustrates an exemplary embodiment of a transceiver **100** that utilizes shared resources. It should be appreciated that numerous functional components of the transceiver have been omitted for clarity. However, the transceiver **100** can also include the standard components found in typical communications device(s) in which the technology of the subject invention is implemented into.

According to an exemplary embodiment of the invention, memory and processing power can be shared among a plurality of transmitter and/or receiver latency paths, in a communications transceiver that carries or supports multiple applications. For example, the transmitter and/or receiver latency paths of the transceiver can share an interleaver/deinterleaver memory and the shared memory can be allocated to the interleaver and/or deinterleaver of each latency path. This allocation can be done based on the data rate, latency, BER, impulse noise protection requirements of the application, data or information being transported over each latency path, or in general any parameter associated with the communications system.

Likewise, for example, the transmitter and/or receiver latency paths can share a Reed-Solomon coder/decoder processing module and the processing power of this module can be allocated to each encoder and/or decoder. This allocation can be done based on the data rate/latency, BER, impulse noise protection requirements of the application data or information being transported over each latency path, or in general based on any parameter associated with the communication system.

In accordance with an exemplary operational embodiment, a first transceiver and a second transceiver transmit to one another messages during, for example, initialization which contain information on the total and/or shared memory capabilities of each transceiver and optionally information about the one or more latency paths. This information can be transmitted prior to determining how to configure the latency paths to support the application requirements. Based on this information, one of the modems can select an FCI configuration parameter(s) that meets the transmission requirements of each application being transported over each latency paths. While an exemplary of the embodiment of the invention will be described in relation to the operation of the invention and characteristics thereof being established during initialization, it should be appreciated that the sharing of resources can be modified and messages transmitted between a two transceivers at any time during initialization and/or user data transmission, i.e., SHOWTIME.

FIG. **1** illustrates an exemplary embodiment of a transceiver **100**. The transceiver **100** includes a transmitter portion **200** and a receiver portion **300**. The transmitter portion **200** includes one or more latency paths **210**, **220**, ... Similarly, the receiver portion **300** includes one or more latency paths **310**, **320**, ... Each of the latency paths in the transmitter portion **200** includes a framer, coder, and interleaver designated as **212**, **214**, **216** and **222**, **224** and **226**, respectively. Each of the latency paths in the receiver portion includes a deframer, decoder, and deinterleaver designated as **312**, **314**, **316** and **322**, **324**, and **326**, respectively. The transceiver **100** further includes a shared processing module **110**, a shared memory **120**, a parameter determination module **130**, a path module **140**, an allocation module **150**, and a shared resource management module **160**, all interconnected by one or more links (not shown).

In this exemplary embodiment, the transceiver **100** is illustrated with four total transmitter portion and receiver portion latency paths, i.e., **210**, **220**, **310**, and **320**. The shared memory **120** is shared amongst the two transmitter portion interleavers **216** and **226** and two receiver portion deinterleavers **316** and **326**. The shared processing module **110**, such

as a shared coding module, is shared between the two transmitter portion coders **214** and **224** and the two receiver portion decoders **314** and **324**.

While the exemplary embodiment of the invention will be described in relation to a transceiver having a number of transmitter portion latency paths and receiver portion latency paths, it should be appreciated that this invention can be applied to any transceiver having any number of latency paths. Moreover, it should be appreciated that the sharing of resources can be allocated such that one or more of the transmitter portion latency paths are sharing a shared resource, one or more of the receiver portion latency paths are sharing a shared resource, or a portion of the transmitter portion latency paths and a portion of the receiver portion latency paths are sharing shared resources. Moreover, any one or more of the latency paths, or portions thereof, could also be assigned to a fixed resource while, for example, another portion of the latency path(s) assigned to a shared resource. For example, in latency path **210**, the interleaver **216** could be allocated a portion of the shared memory **120**, while the coder **214** could be allocated to a dedicated processing module, vice versa, or the like.

In accordance with the exemplary embodiment, a plurality of transmitter portion or receiver portion latency paths share an interleaver/deinterleaver memory, such as shared memory **120**, and a coding module, such as shared processing module **110**. For example, the interleaver/deinterleaver memory can be allocated to different interleavers and/or deinterleavers. This allocation can be based on parameters associated with the communication systems such as data rate, latency, BER, impulse noise protection, and the like, of the applications being transported. Similarly, a coding module, which can be a portion of the shared processing module **110**, can be shared between any one or more of the latency paths. This sharing can be based on requirements such as data rate, latency, BER, impulse noise protection, and the like, of the applications being transported.

For example, an exemplary transceiver could comprise a shared interleaver/deinterleaver memory and could be designed to allocate a first portion of the shared memory **120** to an interleaver, such as interleaver **216** in the transmitter portion of the transceiver and allocate a second portion of the shared memory **120** to a deinterleaver, such as **316**, in the receiver portion of the transceiver.

Alternatively, for example, an exemplary transceiver can comprise a shared interleaver/deinterleaver memory, such as shared memory **120**, and be designed to allocate a first portion of shared memory **120** to a first interleaver, e.g., **216**, in the transmitter portion of the transceiver and allocate a second portion of the shared memory to a second interleaver, e.g., **226**, in the transmitter portion of the transceiver.

Alternatively, for example, an exemplary transceiver can comprise a shared interleaver/deinterleaver memory and be designed to allocate a first portion of the shared memory **120** to a first deinterleaver, e.g., **316**, in the receiver portion of the transceiver and allocate a second portion of the shared memory to a second deinterleaver, e.g., **326**, in the receiver portion of the transceiver. Regardless of the configuration, in general any interleaver or deinterleaver, or grouping thereof, be it in a transmitter portion or receiver portion of the transceiver, can be associated with a portion of the shared memory **120**.

Establishment, configuration and usage of shared resources is performed in the following exemplary manner. First, and in cooperation with the path module **140**, the number of transmitter and receiver latency paths (N) is determined. The parameter determination module **130** then analyses one or more parameters such as data rate, transmitter data rate, receiver data rate, impulse noise protection, bit error rate, latency, or the like. Based on one or more of these parameters, the allocation module **150** allocates a portion of the shared memory **120** to one or more of the interleaver and/or deinterleavers, or groupings thereof. This process continues until the memory allocation has been determined and assigned to each of the N latency paths.

Having determined the memory allocation for each of the latency paths, and in conjunction with the shared resource management **160**, the transceiver **100** transmits to a second transceiver one or more of the number of latency paths (N), the maximum interleaver memory for any one or more of the latency paths and/or the maximum total and/or shared memory for all of the latency paths.

Three examples of sharing interleaver/deinterleaver memory and coding processing in a transceiver are described below. The latency paths in these examples can be in the transmitter portion of the transceiver or the receiver portion of the transceiver.

EXAMPLE #1

A first transmitter portion or receiver portion latency path may carry data from a video application, which needs a very low BER but can tolerate higher latency. In this case, the video will be transported using an latency path that has a large amount of interleaving/deinterleaving and coding (also known as Forward Error Correction (FEC) coding). For example, the latency path may be configured with Reed-Solomon coding using a codeword size of 255 bytes (N=255) with 16 checkbytes (R=16) and interleaving/deinterleaving using an interleaver depth of 64 (D=64). This latency path will require N*D=255*64=16 Kbytes of interleaver memory at the transmitter (or deinterleaver memory at the receiver). This latency path will be able to correct a burst of errors that is less than 512 bytes in duration.

A second transmitter portion or receiver portion latency path may carry an internet access application that requires a medium BER and a medium amount of latency. In this case, the internet access application will be transported using a latency path that has a medium amount of interleaving and coding. For example, the latency path may be configured with Reed-Solomon coding using a codeword size of 128 bytes (N=128) with 8 checkbytes (R=8) and interleaving using an interleaver depth of 16 (D=32). This latency path will require N*D=128*32=4 Kbytes of interleaver memory and the same amount of deinterleaver memory. This latency path will be able to correct a burst of errors that is less than 128 bytes in duration.

A third transmitter portion or receiver portion latency path may carry a voice telephony application, which needs a very low latency but can tolerate BER. In this case, the video will be transported using an latency path that has a large amount of interleaving and coding. For example, the third transmitter portion or receiver portion latency path may be configured with no interleaving or coding which will result in the lowest possible latency through the latency path but will provide no error correction capability.

According to the principles of this invention, a system carrying the three applications described above in Example #1, would have three latency paths that share one memory space containing at least (16+4)=20 Kbytes. The three latency paths also share a common coding block that is able to simultaneously encode (in the transmitter portion) or decode (in a receiver portion) two codewords with N=255/R=16 and N=128/R=8.

According to an exemplary embodiment of this invention, the latency paths can be reconfigured at initialization or during data transmission mode (also known as SHOWTIME in ADSL and VDSL transceivers). This would occur if, for example, the applications or application requirements were to change.

EXAMPLE #2

If instead of 1 video application, 1 internet application and 1 voice application, there were 3 internet access applications then the transmitter portion and/or receiver portion latency paths would be reconfigured to utilize the shared memory and coding module in a different way. For example, the system could be reconfigured to have 3 transmitter portion or receiver portion latency paths, with each latency path being configured with Reed-Solomon coding using a codeword size of 128 bytes (N=128) with 8 checkbytes (R=8) and interleaving using an interleaver depth of 16 (D=32). Each latency path will require N*D=128*32=4 Kbytes of interleaver memory and each block will be able to correct a burst of errors that is less than 128 bytes in duration. Based on the example of carrying the three internet access applications described, the three latency path share one memory space containing at least 3*4=12 Kbytes. Also the three latency paths share a common coding block that is able to simultaneously encode (on the transmitter side) or decode (on the receiver side) three codewords with N=128/R=16, N=128/R=8 and N=128/R=8.

EXAMPLE #3

The system could be configured to carry yet another set of applications. For example, the latency paths could be configured to carry 2 video applications. In this case only 2 transmitter portion or receiver portion latency paths are needed, which means that the third latency path could be simply disabled. Also, assuming that the memory is constrained based on the first example above, then the maximum shared memory for these 2 latency paths is 20 kBytes. In this case, the system could be reconfigured to have 2 latency paths, with each block being configured with Reed-Solomon coding using a codeword size of 200 bytes (N=200) with 10 checkbytes (R=10) and interleaving/deinterleaving using an interleaver depth of 50 (D=50). Each latency path will require N*D=200*50=10 Kbytes of interleaver memory and each block will be able to correct a burst of errors that is less than 250 bytes in duration. This configuration results in 20K of shared memory for both latency paths, which is the same as in the first example. In order to stay within the memory constraints of the latency paths, the error correction capability for each latency path is decreased to 250 bytes from 512 bytes in Example #1.

Another aspect of this invention is the how FCI configuration information is transmitted between a first modem and a second modem. FCI configuration information will depend on the requirements of the applications being transported over the DSL connection. This information may need to be forwarded during initialization in order to initially configure the DSL connection. This information may also need to be forwarded during SHOWTIME in order to reconfigure the DSL connection based on a change in applications or the application requirements.

According to one embodiment, a first modem determines the specific FCI configuration parameters, e.g.,. N, D, R as defined above, needed to meet specific application requirements, such as latency, burst error correction capability, etc. In order to determine the FCI configuration parameters, the first modem must know what are the capabilities of a second modem. For example, the first modem must know how many latency paths (FCI blocks) the second modem can support. Also the first modem must know the maximum amount of interleaver memory for each transmitter latency path. In addition, since the transmitter latency paths may share a common memory space the first modem must know the total shared memory for all transmitter latency paths. This way the first modem will be able to choose a configuration that can meet application requirements and also meet the transmitter portion latency path capabilities of the second modem.

For example, using values from examples above, a first transceiver could send a message to a second transceiver during initialization or during SHOWTIME containing the following information:

Number of supported transmitter and receiver latency paths=3
Max Interleaver Memory for latency path #1=16 Kbytes
Max Interleaver Memory for latency path #2=16 Kbytes
Max Interleaver Memory for latency path #3=16 Kbytes
Maximum total/shared memory for all latency paths=20 kBytes

Based on this information, and the application requirements, the first transceiver would select latency path settings. For example, if the applications are 1 video, 1 internet access and 1 voice application, the first transceiver could configure 3 latency paths as follows:

latency path #1—Video: N=255, R=16, D=64
latency path #2—Video: N=128, R=8, D=32
latency path #3—Video: N=0, R=0, D=1 (no coding or interleaving)

This would result in a total interleaver memory of 20 kbytes.

Alternatively, if for example, there are only 2 video applications, the first transceiver could configure 2 latency paths as follows:

latency path #1—Video: N=200, R=10, D=50
latency path #2—Video: N=200, R=10, D=50
latency path #3—Video: N=0, R=0, D=1 (no coding or interleaving)

This would also result in a total interleaver memory of 20 kbytes.

Alternatively, the second transceiver can determine the specific FCI configuration parameters, e.g., N, D, R as defined above, needed to meet specific application requirements, such as latency, burst error correction capability, etc. As described above for the first transceiver, in order to determine the FCI configuration parameters, the second transceiver must first know what are the capabilities of the first transceiver. In this case, the first transceiver would send a message to the second transceiver containing the information described above and based on this information and the application requirements the second transceiver would select latency path settings.

FIG. **2** outlines an exemplary method of allocating shared memory in a transceiver. More specifically, control begins in step S**200** and continues to step S**210**. In step S**210**, one or more of shared interleaver/deinterleaver memory and/or shared coder/decoder processing resources are allocated to one or more latency paths, in a transceiver. Control then continues to step S**220** where the control sequence ends.

FIG. **3** outlines an exemplary method of exchanging shared resource allocations according to an exemplary embodiment of this invention. In particular, control begins in step S**310**. In step S**310**, a maximum amount of shared memory that can be allocated to a specific interleaver or deinterleaver of a plurality of interleavers or deinterleavers in a transceiver is deter-

mined. Next, in step S**320**, the determined maximum amount for one or more of the deinterleavers and/or interleavers is transmitted to another transceiver. Messages containing additional information can also be transmitted to the other transceiver and/or received from the other transceiver. Control then continues to step S**330** where the control sequence ends.

FIG. **4** outlines an exemplary procedure for resource sharing according to an exemplary embodiment of this invention. In particular, control begins in step S**400** and continues to step S**410**. In step S**410**, the number of latency paths are determined Then, in step S**420**, the latency path information (FCI block information) is transmitted to another transceiver. Messages containing additional information can also be transmitted to the other transceiver and/or received from the other transceiver. This information can be used to, for example, assist with the determination of memory allocation in the transceiver. Moreover, the messages received from the other transceiver could specify what the memory allocation is to be based on, for example, the number of latency paths, memory allocation in the remote transceiver and required applications. Control then continues to step S**430**.

In step S**430**, and for each latency path, the steps in step **440** are performed.

In step S**440**, and while monitoring of allocation of resources is being performed, steps **450** and **460** are performed. More specifically, in step S**450**, one or more parameters associated with the communication system are determined. Then, in step S**460**, shared resources are allocated based on one or more of the communication parameters. Control then continues to step S**470**.

In step S**470**, the allocation of shared resources is communicated to another transceiver. Next, in step S**480**, a determination is made as to whether there is a change in communications that would require the adjustment of the shared resource allocation. Examples of changes in communications conditions include a change in applications being transported over the system and/or changes in the channel condition, etc. If adjustments are required, control jumps back to step S**410**. Otherwise, control jumps to step S**490** where the control sequence ends.

The above-described system can be implemented on wired and/or wireless telecommunications devices, such a modem, a multicarrier modem, a DSL modem, an ADSL modem, an XDSL modem, a VDSL modem, a linecard, test equipment, a multicarrier transceiver, a wired and/or wireless wide/local area network system, a satellite communication system, a modem equipped with diagnostic capabilities, or the like, or on a separate programmed general purpose computer having a communications device or in conjunction with any of the following communications protocols: CDSL, ADSL2, ADSL2+, VDSL1, VDSL2, HDSL, DSL Lite, IDSL, RADSL, SDSL, UDSL or the like.

Additionally, the systems, methods and protocols of this invention can be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, a modem, a transmitter/receiver, any comparable means, or the like. In general, any device capable of implementing a state machine that is in turn capable of implementing the methodology illustrated herein can be used to implement the various communication methods, protocols and techniques according to this invention.

Furthermore, the disclosed methods may be readily implemented in software using object or object-oriented software

development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed system may be implemented partially or fully in hardware using standard logic circuits or VLSI design. Whether software or hardware is used to implement the systems in accordance with this invention is dependent on the speed and/or efficiency requirements of the system, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The communication systems, methods and protocols illustrated herein can be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods may be readily implemented in software that can be stored on a storage medium, executed on programmed general-purpose computer with the cooperation of a controller and memory, a special purpose computer, a microprocessor, or the like. In these instances, the systems and methods of this invention can be implemented as program embedded on personal computer such as an applet, JAVA® or CGI script, as a resource residing on a server or computer workstation, as a routine embedded in a dedicated communication system or system component, or the like. The system can also be implemented by physically incorporating the system and/or method into a software and/or hardware system, such as the hardware and software systems of a communications transceiver.

It is therefore apparent that there has been provided, in accordance with the present invention, systems and methods for sharing resources. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable arts. Accordingly, it is intended to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and scope of this invention.

The invention claimed is:

1. A system that allocates shared memory comprising:

a transceiver that is capable of:

transmitting or receiving a message during initialization specifying a maximum number of bytes of memory that are available to be allocated to an interleaver;

determining an amount of memory required by the interleaver to interleave a first plurality of Reed Solomon (RS) coded data bytes within the shared memory;

allocating a first number of bytes of the shared memory to the interleaver to interleave the first plurality of Reed Solomon (RS) coded data bytes for transmission at a first data rate, wherein the allocated memory for the interleaver does not exceed the maximum number of bytes specified in the message;

allocating a second number of bytes of the shared memory to a deinterleaver to deinterleave a second plurality of RS coded data bytes received at a second data rate; and

interleaving the first plurality of RS coded data bytes within the shared memory allocated to the interleaver and deinterleaving the second plurality of RS coded data bytes within the shared memory allocated to the deinterleaver, wherein the shared memory allocated to the interleaver is used at the same time as the shared memory allocated to the deinterleaver.

2. The system of claim **1**, wherein the determining is based on an impulse noise protection requirement.

3. The system of claim **1**, wherein the determining is based on a latency requirement.

4. The system of claim **1**, wherein the determining is based on a bit error rate requirement.

5. A system that allocates shared memory comprising:

a transceiver that is capable of:

transmitting or receiving a message during initialization specifying a maximum number of bytes of memory that are available to be allocated to a deinterleaver;

determining an amount of memory required by the deinterleaver to deinterleave a first plurality of Reed Solomon (RS) coded data bytes within the shared memory;

allocating a first number of bytes of the shared memory to the deinterleaver to deinterleave a first plurality of Reed Solomon (RS) coded data bytes for transmission at a first data rate, wherein the allocated memory for the deinterleaver does not exceed the maximum number of bytes specified in the message;

allocating a second number of bytes of the shared memory to an interleaver to interleave a second plurality of RS coded data bytes received at a second data rate; and

deinterleaving the first plurality of RS coded data bytes within the shared memory allocated to the deinterleaver and interleaving the second plurality of RS coded data bytes within the shared memory allocated to the interleaver, wherein the shared memory allocated to the deinterleaver is used at the same time as the shared memory allocated to the interleaver.

6. The system of claim **5**, wherein the determining is based on an impulse noise protection requirement.

7. The system of claim **5**, wherein the determining is based on a latency requirement.

8. The system of claim **5**, wherein the determining is based on a bit error rate requirement.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,276,048 B2
APPLICATION NO. : 12/901699
DATED : September 25, 2012
INVENTOR(S) : Marcos C. Tzannes et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims:

At Column 11, Claim 5, line 16, delete “transmission” and insert -- reception --

At Column 12, Claim 5, line 3, delete “received” and insert -- transmitted --

Signed and Sealed this
Twenty-eighth Day of October, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office

US008462835B2

(12) **United States Patent**
Tzannes

(10) **Patent No.: US 8,462,835 B2**
(45) **Date of Patent: Jun. 11, 2013**

(54) **IMPULSE NOISE MANAGEMENT**

(75) Inventor: **Marcos C. Tzannes**, Orinda, CA (US)

(73) Assignee: **TQ Delta, LLC**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/769,193**

(22) Filed: **Apr. 28, 2010**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 10/597,482, filed as application No. PCT/US2005/006842 on Mar. 3, 2005, now abandoned.

(60) Provisional application No. 60/549,804, filed on Mar. 3, 2004, provisional application No. 60/555,982, filed on Mar. 24, 2004.

(51) **Int. Cl.**
H04B 1/38 (2006.01)
H04L 5/16 (2006.01)

(52) **U.S. Cl.**
USPC **375/219**; 375/224; 375/284; 375/346

(58) **Field of Classification Search**
USPC 375/219, 224, 285, 346; 714/774, 714/786
See application file for complete search history.

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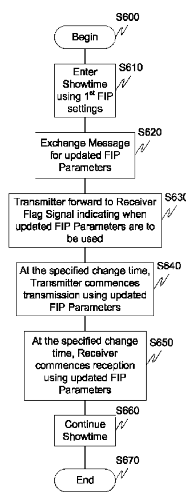
Primary Examiner — Jean B Corrielus
(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross, PC

(57) **ABSTRACT**

Evaluation of the impact of impulse noise on a communication system can be utilized to determine how the system should be configured to adapt to impulse noise events. Moreover, the system allows for information regarding impulse noise events, such as length of the event, repetition period of the event and timing of the event, to be collected and forwarded to a destination. The adaptation can be performed during one or more of Showtime and initialization, and can be initiated and determined at either one or more of a transmitter and a receiver.

32 Claims, 7 Drawing Sheets



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Invitation to Pay Additional Fees for International (PCT) Patent Application No. PCT/US2005/006842, mailed Jul. 28, 2005.

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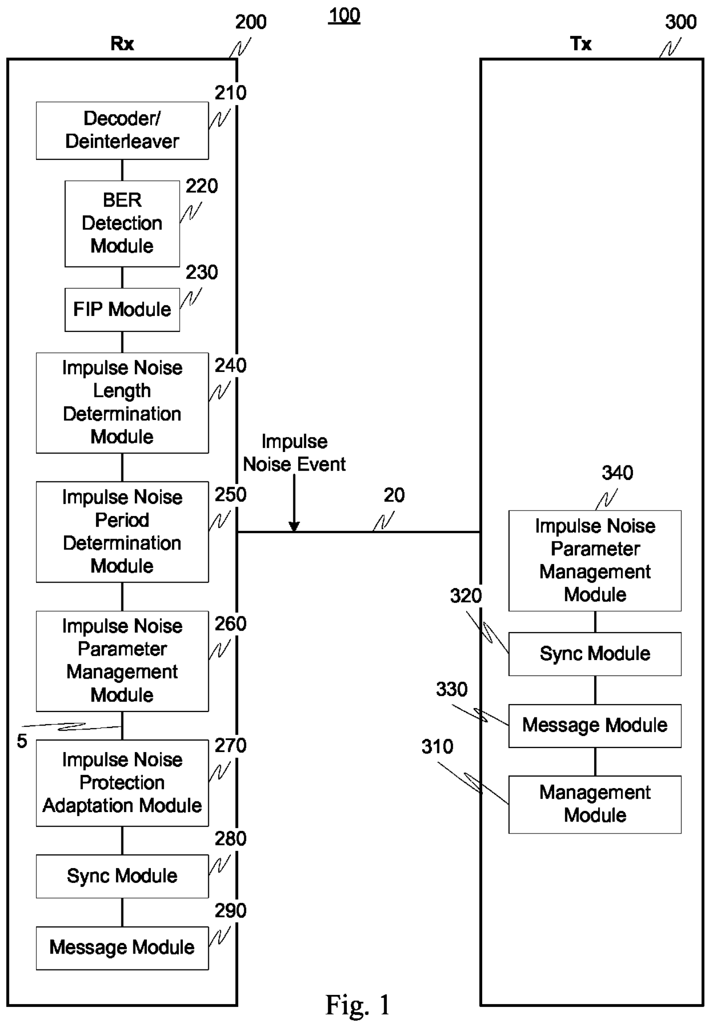
100
Rx
200
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Decoder/ Deinterleaver
220
BER Detection Module
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FIP Module
240
Impulse Noise Length Determination Module
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Impulse Noise Period Determination Module
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Impulse Noise Parameter Management Module
5
270
Impulse Noise Protection Adaptation Module
280
Sync Module
290
Message Module
Impulse Noise Event
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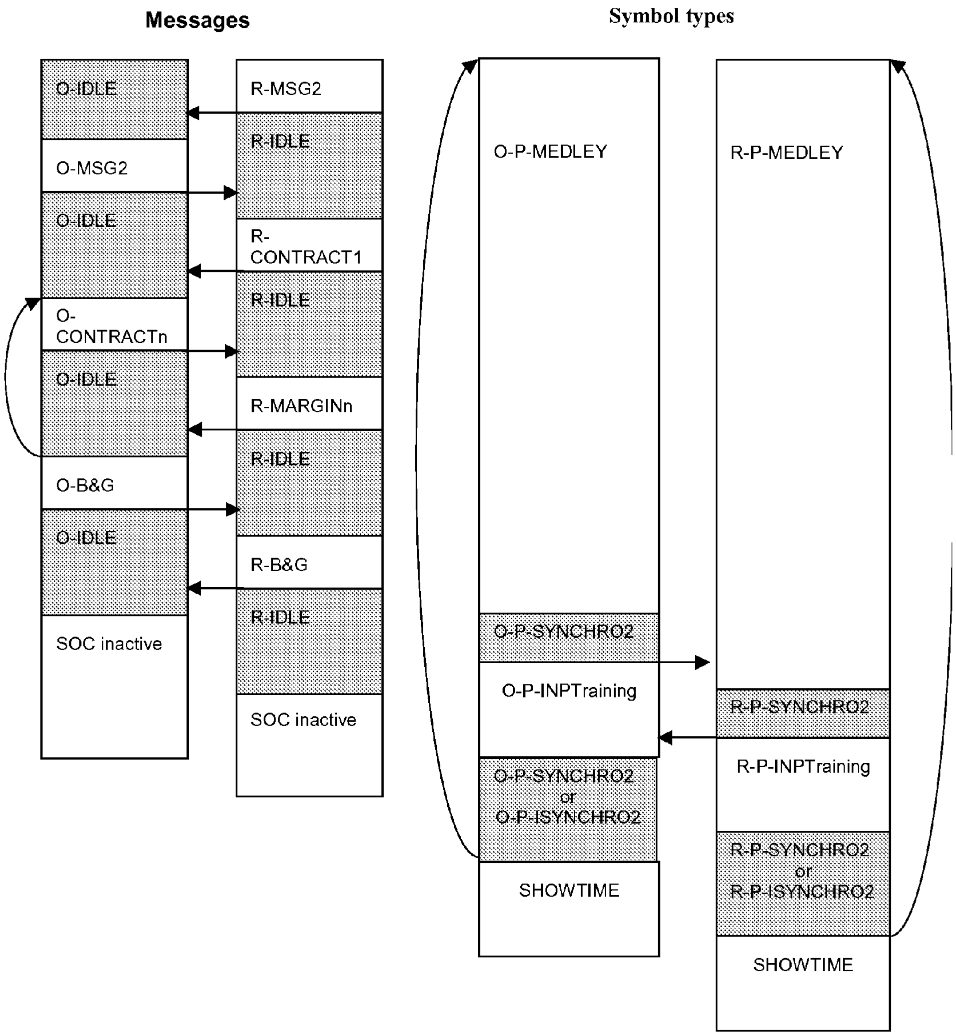
Tx
300
340
Impulse Noise Parameter Management Module
320
Sync Module
330
Message Module
310
Management Module

Fig. 1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O-IDLE
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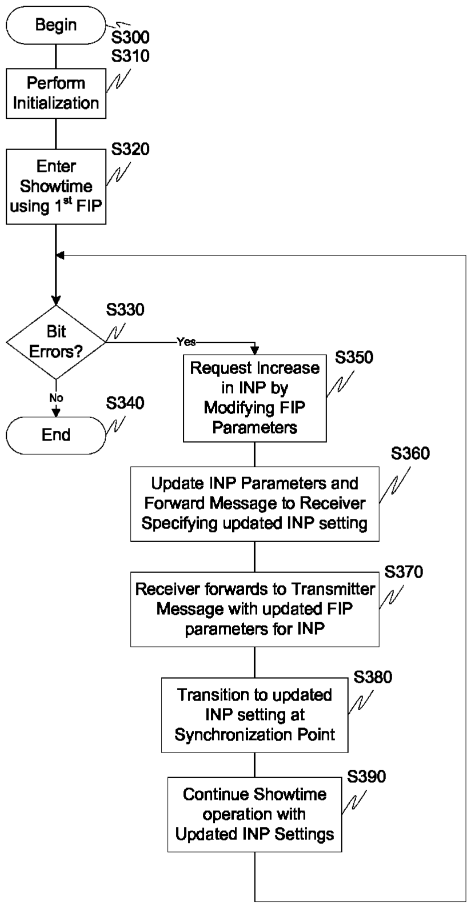
R-CONTRACT1
R-IDLE
R-MARGINn
R-IDLE
R-B&G
R-IDLE
SOC inactive
O-P-MEDLEY
O-P-SYNCHRO2
O-P-INPTraining
O-P-SYNCHRO2 or O-P-ISYNCHRO2
SHOWTIME
R-P-MEDLEY
R-P-SYNCHRO2
R-P-INPTraining
R-P-SYNCHRO2 or R-P-ISYNCHRO2
SHOWTIME

Fig. 2



Begin
S300
S310
Perform Initialization
S320
Enter Showtime using 1st FIP
S330
Bit Errors?
Yes
No
S340
End
S350
Request Increase in INP by Modifying FIP Parameters
S360
Update INP Parameters and Forward Message to Receiver Specifying updated INP setting
S370
Receiver forwards to Transmitter Message with updated FIP parameters for INP
S380
Transition to updated INP setting at Synchronization Point
S390
Continue Showtime operation with Updated INP Settings

Fig. 3

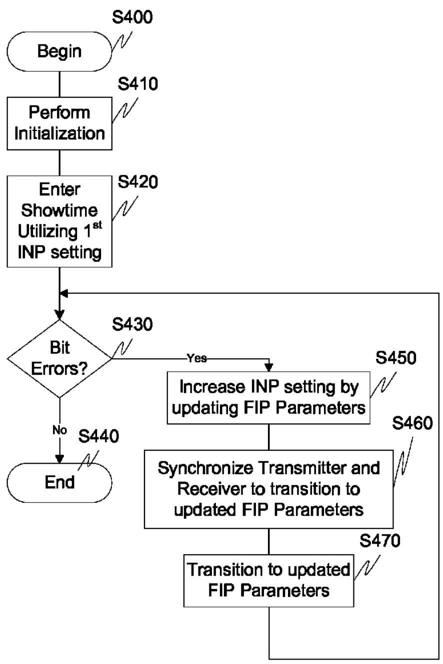

S400
Begin
S410
Perform Initialization
S420
Enter Showtime Utilizing 1st INP setting
S430
Bit Errors?
Yes
S450
Increase INP setting by updating FIP Parameters
S460
Synchronize Transmitter and Receiver to transition to updated FIP Parameters
S470
Transition to updated FIP Parameters
No
S440
End

Fig. 4

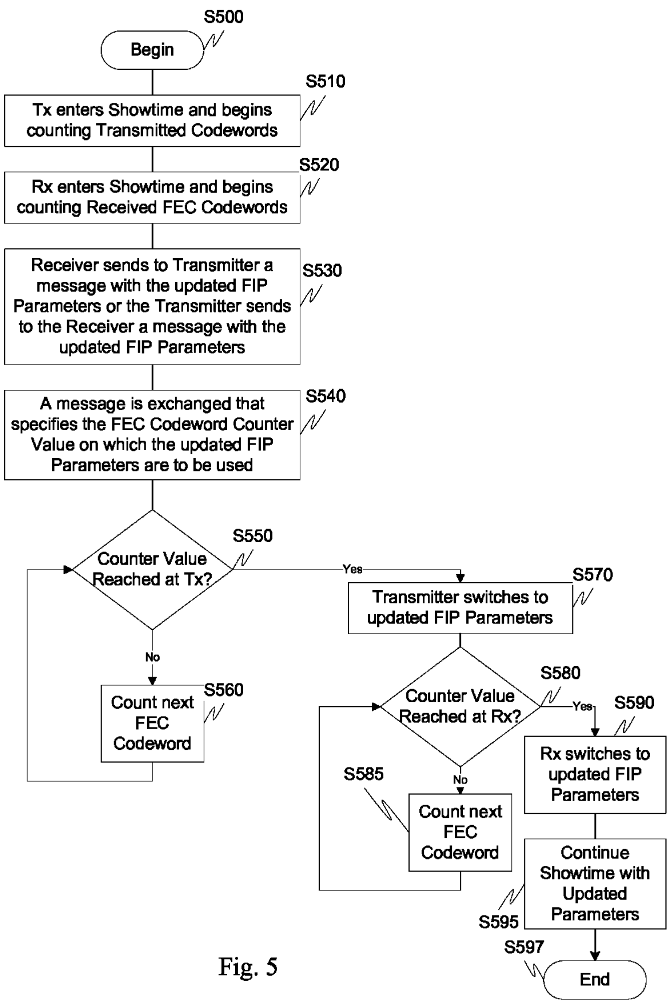

S500
Begin
S510
Tx enters Showtime and begins counting Transmitted Codewords
S520
Rx enters Showtime and begins counting Received FEC Codewords
S530
Receiver sends to Transmitter a message with the updated FIP Parameters or the Transmitter sends to the Receiver a message with the updated FIP Parameters
S540
A message is exchanged that specifies the FEC Codeword Counter Value on which the updated FIP Parameters are to be used
S550
Counter Value Reached at Tx?
Yes
No
S560
Count next FEC Codeword
S570
Transmitter switches to updated FIP Parameters
S580
Counter Value Reached at Rx?
Yes
No
S585
Count next FEC Codeword
S590
Rx switches to updated FIP Parameters
Continue Showtime with Updated Parameters
S595
S597
End

Fig. 5

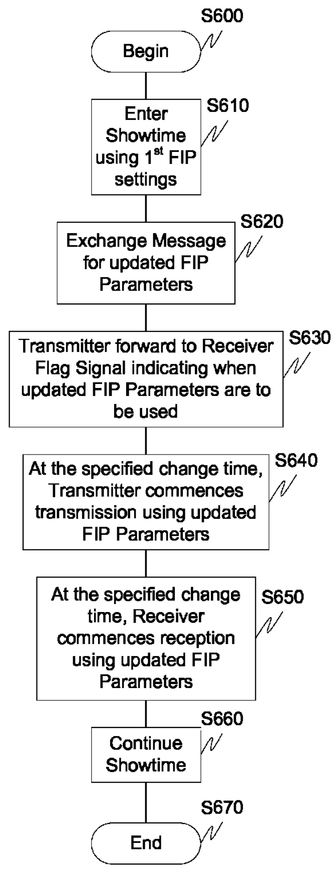

S600
Begin
S610
Enter Showtime using 1st FIP settings
S620
Exchange Message for updated FIP Parameters
S630
Transmitter forward to Receiver Flag Signal indicating when updated FIP Parameters are to be used
S640
At the specified change time, Transmitter commences transmission using updated FIP Parameters
S650
At the specified change time, Receiver commences reception using updated FIP Parameters
S660
Continue Showtime
S670
End

Fig. 6

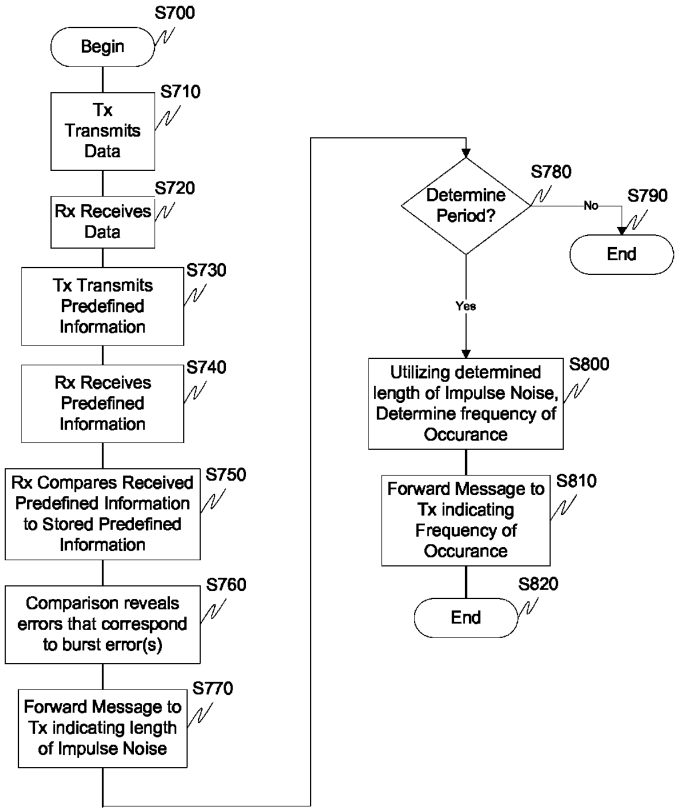

S700
Begin
S710
Tx Transmits Data
S720
Rx Receives Data
S730
Tx Transmits Predefined Information
S740
Rx Receives Predefined Information
S750
Rx Compares Received Predefined Information to Stored Predefined Information
S760
Comparison reveals errors that correspond to burst error(s)
S770
Forward Message to Tx indicating length of Impulse Noise
S780
Determine Period?
No
S790
End
Yes
S800
Utilizing determined length of Impulse Noise, Determine frequency of Occurance
S810
Forward Message to Tx indicating Frequency of Occurance
S820
End

Fig. 7

IMPULSE NOISE MANAGEMENT

RELATED APPLICATION DATA

This application is a continuation of U.S. application Ser. No. 10/597,482, filed Jul. 27, 2006 now abandoned, which is a national stage application under 35 U.S.C. 371 of PCT Application No. PCT/US2005/006842, filed Mar. 3, 2005, which claims the benefit of and priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 60/549,804, entitled "On-Line Impulse Noise Protection (INP) Adaptation," filed Mar. 3, 2004, and U.S. Provisional Application No. 60/555,982, entitled "Impulse Noise Protection (INP) Training," filed Mar. 24, 2004, each of which are incorporated herein by reference in their entirety.

BACKGROUND

1. Field of the Invention

This invention generally relates to communication systems. In particular, an exemplary aspect of this invention relates to impulse noise protection adaptation. Another exemplary aspect of this invention relates to impulse noise length and period determination and use thereof for impulse noise protection adaptation.

2. Description of Related Art

Communications systems often operate in environments that produce impulse noise. Impulse noise is a short-term burst of noise that is higher than the normal noise that typically exists in a communication channel. For example, DSL systems operate on telephone lines and experience impulse noise from many external sources including telephones, AM radio, HAM radio, other DSL services on the same line or in the same bundle, other equipment in the home, etc. It is standard practice for communications systems to use interleaving in combination with Forward Error Correction (FEC) to correct the errors caused by impulse noise. Standard initialization procedures in ADSL and VDSL systems are designed to optimize performance (data rate/reach) in the presence "stationary" crosstalk or noise. Impulse noise protection is handled with interleaving and FEC, but the current xDSL procedure at least does not provide specific states to enable training for the selection of the appropriate interleaving and FEC parameters.

An exemplary problem associated with traditional communication systems is that they use traditional Signal to Noise Ratio (SNR) measurement techniques to determine the SNR of the channel. These traditional techniques assume that the noise is stationary and does not contain non-stationary components such as impulse noise. The most common method for measuring the SNR is to calculate the mean-square error of the received signal based on a known transmitted signal, which is described in the ADSL series of ITU G.992.x standards and the VDSL series of ITU G.993.x standards, which are incorporated herein by reference in their entirety. These traditional methods for measuring SNR do not correctly measure the impact of impulse noise and do not have the noise capability to determine how the system should be configured to handle impulse noise.

There has been proposed that there is a need in ADSL and VDSL systems to provide robust error-free performance in the presence of high, real-world impulse noise. A specific proposal recommends that the standard impulse noise protection (INP) values are extended to values of 4, 8, 16 and 32 in order to handle high levels of impulse noise. Impulse noise protection is defined in the ADSL2 Standard G.992.3, which is incorporated herein by reference in its entirety, as the number of impulse noise corrupted DMT symbols that can be corrected by the FEC and interleaving configuration. Specifically, G.992.3 defines the following variables:

$$\mathrm{INP}=1/2*(S*D)*R/N$$

$$S=8*N/L$$

$$\text{Latency (or delay)}=S*D/4$$

$$\text{Line Rate (in kbps)}=L*4$$

where N is the codeword size in bytes, R is the number of parity (or redundancy) bytes in a codeword, D is the interleaver depth in number of codewords, and L is the number of bits in a DMT symbol.

If K is the number of information bytes in a codeword then:

$$N=K+R$$

and the user data rate is approximately equal to:

$$L*4*K/N.$$

In general, DSL systems (such as the one defined in ADSL G.992.x or VDSL G.993.x) use the FEC and Interleaving Parameters (FIP) characterized by the set of parameters (N, K, R, D). Using these parameters, the Burst Error Correction Capability (BECC) in bytes can be simply calculated as:

$$\text{BECC}=D*R/2\text{ bytes}$$

where BECC is defined as the number of consecutive byte errors that can be corrected by the receiver. Note that if the receiver uses more intelligent decoding schemes, such as erasure detection, it is possible to correct even more than D*R/2 bytes. It also follows from above that INP=BECC/L.

The proposal further recommends that the higher INP values are achieved by increasing the amount of FEC redundancy while keeping the same system latency and the same interleaver memory at the expense of user data rate or excess margin. Since, on phone lines without excess margin, there is clearly a trade-off between high impulse noise protection values and user data rate, it would be advantageous to try to maximize the user data rate by finding the minimum impulse noise protection value that can provide adequate impulse noise protection. The current technique includes the steps of an operator, or service provider, configuring the ADSL connection with a specific noise protection value, the ADSL connection is initialized and the transceivers enter into steady state data transmission (i.e., Showtime), and if the connection is stable, i.e., error-free, then the service is acceptable and the process ends. If there are bit errors, then the process is repeated with the operator, or service provider, configuring the ADSL connection with another specific INP value.

One exemplary problem with this approach is that it is time consuming and can result in sub-optimum user rates. This is illustrated with reference to the following examples:

Example 1: Assume that for a particular DSL connection there is high impulse noise and the required INP is 8. As a result, if the service provider uses a first INP configuration of 2, the DSL connection will not be error free. Therefore, the service provider needs to configure a higher INP value and reinitialize the connection. If a value of 4 is used as a second INP value, it still will not provide adequate impulse noise protection and bit errors will occur. Again, the service provider will need to configure a higher INP value until the correct value of 8 is configured. Clearly, the connection needs to be re-initialized every time there is a new INP configuration chosen and this trial and error technique proves to be very time consuming

Example 2: Assume that for a particular DSL connection there is high-impulse noise and the required INP is 4. As a result, if the service provider uses a first INP configuration of 2, the connection will not be error free. Therefore, the service provider needs to configure a higher INP value and reinitialize the connection. In order to save time and not go through the number of initializations has occurred in Example 1, the service provider simply configures the system to the maximum INP value of 32. Obviously, there will be no bit errors with INP=32 since this connection needs only an INP value of 4. As a result, user data throughput is greatly degraded since the additional FEC redundancy will be three times higher than what is actually needed. For example, if the INP of 4 requires 10 percent FEC redundancy, an INP of 32 requires 40 percent FEC redundancy which results in a 30 percent decrease in user data rate.

SUMMARY

In additional to the above drawbacks, the related systems do not have the ability to actually measure the length or repetition period of impulse noise which can both be used to determine an appropriate impulse noise protection setting.

Exemplary aspects of this invention relate to determining the impact of impulse noise on a communication system and the capability to determine how the system should be configured to handle the impulse noise event.

An exemplary aspect of this invention determines the impact of impulse noise by transmitting and receiving using a plurality of different FEC and interleaving parameter settings. For each FEC and Interleaving Parameter (FIP) setting, the received signal quality is determined by, for example, detecting if there are bit errors after the receiver performs the FEC decoding and deinterleaving. Based on this, the appropriate FIP setting is selected and used for transmission and reception.

A plurality of FIP settings can be used for transmission and reception. In accordance with one particular aspect of this invention, the system can transition from one FIP setting to another FIP setting without going through the startup initialization procedure such as the startup initialization sequence utilized in traditional xDSL systems. For example, an xDSL system that implements the systems and methods described herein could start using an FIP setting of (N=255, K=247, R=8, D=64) and then transition to an FIP setting of (N=255, K=239, R=16, D=64) without re-executing the startup initialization procedure.

Knowing that the first FIP setting has a BECC=256 bytes and the second setting has a BECC=512 bytes, means, for example, that the second setting can correct an impulse that causes twice as many bit errors as the first FIP setting. On the other hand, the first FIP setting has less FEC parity (overhead) which results in a higher information (net) data rate for the user during Showtime. This is also illustrated by the fact that K, the number of information bytes per code word, is higher for the first FIP setting. For each of the FIP settings, the receiver detects whether there are bit errors after the decoding and deinterleaving process. This detection can be done by, for example, by performing a cyclic redundancy check (CRC) after the decoding and deinterleaving process is complete as defined in the ITU standard G.992.x. In general, the CRC is a well-known method for detecting bit errors. Since impulse noise occurs at random times, this system can operate using a particular FIP setting for a period of time that is sufficient to encounter the impulse noise. In the simple example illustrated above, only the K and R values were modified. It should be appreciated however, that the systems and methods of this

invention are not limited thereto but rather can be extended to include the modification of any one or more FIP parameter(s).

The process of determining the impact of impulse noise by transmitting and receiving using a plurality of FIP settings can be done while in steady-state transmission, i.e., Showtime for DSL systems, when user information bits are being transmitted.

The process of determining the impact of impulse noise by transmitting and receiving using a plurality of FIP settings, can be done during a special impulse noise training period during which the system is not actually transmitting user data. In accordance with this exemplary aspect of the invention, the standard xDSL procedure is modified to include the capability of measuring the effectiveness of a chosen impulse noise protection (INP) setting during initialization and having receiver-controlled updates of transmission parameters that control the INP setting, e.g., FEC parameters and interleaving parameters, during initialization.

A new initialization state is included in the xDSL initialization procedure that provides the capability to measure the effectiveness of the current INP settings. The new initialization state will be referred to as the INPTraining state and it can, for example, follow the exchange of the Showtime transmission parameters such as the bi/gi table, trellis coding, tone reordering, FEC/interleaving parameters, etc. It is important to note that steady-state transmission during which user information is transmitted is known as “Showtime” in XDSL systems and that standard ITU G.992.3 ADSL systems and ITU VDSL G.993.3 systems include an exchange phase in initialization during which the Showtime parameters are exchanged, see, for example, G.992.3 and G.993.1.

During this INPTraining state, the transceivers transmit and receive using at least one of the standard Showtime functions using the Showtime parameters, e.g., bi/gi table, FEC/interleaving parameters, etc., that are exchanged during the previous exchange phase. These functions include at least one of Showtime PMD functions, e.g., bi/gi table, trellis coding, tone reordering, etc., PMS-TC functions, such as framing and FEC/interleaving, and TPS-TC functions. During the INPTraining state, the TPS-TC can transmit idle ATM cells, HDLC flags, or 64/65 idle packets depending on the TPS-TC type.

At the receiver, the CRC, the FEC, the TPS-TC error detection capabilities, and other receiver functions can be used to determine whether the INP setting is adequate for the current impulse noise conditions on the line. The receiver can also use these receiver functions to automatically and dynamically determine what the correct INP setting should be. If the current INP setting is not adequate, a new set of Showtime transmission parameters can be exchanged and the process repeated by reentering the INPTraining state using the newly exchanged Showtime transmission parameters. If, on the other hand, the current INP setting is adequate, the transceivers can enter into Showtime.

An exemplary advantage associated with this aspect of the invention is that the receiver can measure the effectiveness of the current INP setting and can make updates to the INP setting based on these measurements during initialization. This is important because the receiver generally has the most knowledge of channel conditions, receiver functionality, and processing capability. In general, the receiver has the best capability to make the necessary trade offs between data rate, latency, excess margin, FEC redundancy, coding gain, and the like. Current related ADSL systems have the operator servicing lines that are experiencing high impulse noise by trying various INP settings in an attempt to find an error-free operating mode. However, since the operator is not capable of

making the receiver trade offs stated above, such as the data rate, latency, and the like, the process will often lead to a sub-optimum result.

Another exemplary aspect of this invention relates to determining the length and/or repetition period of impulse noise events in order to select an appropriate INP setting.

For example, the transceivers can transmit and receive using at least one of the standard Showtime functions and parameters such as the bi/gi table, FEC/interleaving parameters, and the like. These functions include the Showtime PMD functions, such as the bi/gi table, trellis coding, tone reordering and the like, PMS-TC functions (such as framing and FEC interleaving) and TPS-TC functions. The TPS-TC may transmit ATM cells, HDLC packets, or 64/65 packets depending on, for example, the TPS-TC type.

At the receiver, the CRC, the FEC, the TPS-TC error detection capabilities, and other receiver functions can be used to determine the length and the period of the impulse noise and whether an INP setting is adequate for the current impulse noise conditions on the line.

For example, the receiver can determine the length of an impulse noise event. The length of impulse noise events can be determined in a number of ways. For example, they can be determined as:

1. The length of the impulse in time, e.g., how many microseconds the impulse power is above a specific noise level (e.g. the above the stationary channel noise)
2. The number received bits that are affected by the impulse noise, e.g. how many received bits are in error in a specific sliding time window or how many consecutive bits are in error in a stream
3. The number of received ATM cells that are affected by the impulse noise, e.g. how many ATM cells contain bits that are in error. This may be detected using a standard ATM HEC, which is a CRC that covers the ATM header bits. Alternatively this may detected by checking the ATM payload bits by, for example, transmitting a predefined bit pattern that is known by the receiver
4. The number of 64/65 packets that are affected by the impulse noise, e.g. how many packets contain bits that are in error (the 64/65 CRC can be used for this)
5. The number of received DMT symbols that are affected by the impulse noise, e.g., the measured noise in a DMT symbol is above a predefined threshold which results in most (if not all) the bits in that DMT symbol being in error
6. The number of FEC codewords that are affected by the impulse noise, e.g., how many codewords have an uncorrectable number of bit errors, i.e., the number of bit errors in a codeword exceeds the number of bit that are correctable by the FEC code

In accordance with one exemplary aspect, the FEC correction capability and interleaving is turned off when trying to determine the length of the impulse noise. For example, the FEC may be configured so that there are no parity bits (i.e., R=0) or the FEC may be disabled altogether (i.e., no codewords are sent). Additionally, for example, the interleaving may be disabled by setting the interleaver depth to 1 (i.e., D=1). Disabling the FEC and interleaving is beneficial when trying to determine the length of the impulse noise based on affected bits, affected code words and/or affected packets. This is true since when the FEC/interleaving is enabled, the impulse noise event will be spread over a large time period and it will be more difficult to determine the length of the original impulse.

The exemplary techniques discussed herein that are used to determine the length of the impulse event can also be extended to determining the repetition period of the impulse noise event, i.e., how often is impulse noise occurring. The repetition period can be important, because the period has an effect on the FIP setting that is used. For example, if the interleaving spreads an impulse noise event over a period of time that exceeds the impulse period, then the interleaver could combine multiple impulse noise events together. As a result, the FEC correction capability may have to be increased. In order to determine the repetition period of an impulse noise event, the receiver can first detect the impulse noise event as discussed above and then determine how often the impulse noise events occur. For example, periodic impulse noise due to AC power lines occurs at a 120 Hz reception rate, or approximately every 8 ms.

In the case where the impulse noise does not have a fixed length, i.e., where the impulse noise varies over time, the receiver can attempt to determine the maximum impulse noise length. This involves measuring several impulse noise events and determining the impulse noise event with the maximum length. In practice, it is likely that the impulse noise will have varying length and it is important that the FEC/interleaving settings be configured to handle the maximum, e.g., worst case, impulse noise event.

Once the receiver determines the (maximum) length of the impulse noise and/or the repetition period of the impulse noise, this information can be sent to the transmitting modem. In particular, when the receiving modem, such as a Customer-Premises (CPE) modem determines the (maximum) length of the impulse and/or the repetition period of the impulse, the CPE modem could send the information to a Central Office (CO) modem in a message. The length of the impulse length event can be defined and specified in the message in terms of time, received bits, ATM cells, 64/65 packets, DMT symbols, or the like. The CO modem could then, for example, provide this information to the CO-MIB, which is the management interface that is used by the operator or service provider to configure the modems. For example, based on this information, the operator may configure the modems to a different INP value, data rate, latency, or the like. This process could also be automated such that the message received by the CO modem allows automatic reconfiguration to adjust, for example, INP values, data rate, latency, or the like.

The exemplary aspects of the invention that are used to determine the length and/or repetition period of the impulse noise event can be performed during initialization and/or Showtime. During initialization, the method can perform during an INPTraining state such as the one described herein. During Showtime the method can be performed, for example, during a Showtime INP adaptation phase as described herein.

These and other features and advantages of this invention are described in, or are apparent from, the following description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of this invention will be described in relation to the figures, wherein:

FIG. **1** is a functional block diagram illustrating an exemplary impulse noise adaptation system according to this invention;

FIG. **2** illustrates an exemplary initialization state machine that includes an INPTraining state according to this invention;

FIG. **3** is a flowchart outlining an exemplary method for impulse noise protection adaptation during Showtime according to this invention;

FIG. **4** is a flowchart illustrating an exemplary receiver optimized method for impulse noise protection adaptation according to this invention;

FIG. **5** is a flowchart illustrating an exemplary method for forward error correction synchronization according to this invention;

FIG. **6** is a flowchart illustrating an exemplary method for flag signal synchronization according to this invention; and

FIG. **7** is a flowchart illustrating an exemplary method for determining impulse noise length and period according to this invention.

DETAILED DESCRIPTION

The exemplary embodiments of this invention will be described in relation to adapting impulse noise parameters as well as measuring impulse noise length and repetition period within an xDSL environment. However, it should be appreciated that, in general, the systems and methods of this invention can be applied and will work equally well with any type of communication system in any environment.

The exemplary systems and methods of this invention will be described in relation to xDSL modems and associated communication hardware, software, and communication channels. However, to avoid unnecessarily obscuring the present invention, the following description omits well-known structures and devices that may be shown in block diagram form or otherwise summarized.

For purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the present invention. It should be appreciated however, that the present invention may be practiced in a variety of ways beyond the specific details set forth herein. For example, the systems and methods of this invention can generally be applied to any type of system within any environment in which the impulse noise length and/or period is desired, or for which impulse noise adaptation is desired.

Furthermore, while the exemplary embodiments illustrated herein show the various components of the system collocated in specific locations, it is to be appreciated that the various components of the system can be located or relocated at distant portions of a distributed network, such as a telecommunications network and/or the Internet, or within a dedicated secure, unsecured and/or encrypted system. Thus, it should be appreciated that the components of the system can be combined into one or more devices, such as a modem, or collocated on a particular node of a distributed network, such as a telecommunications network. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the system can be arranged at any location within a distributed network without effecting the operation of the system. For example, the various components can be located in a central office (CO or ATU-C) modem, a customer premises modem (CPE or ATU-R), or some combination thereof. Similarly, the functionality of the system could be distributed between one or more of the modems and an associated computing device.

Furthermore, it should be appreciated that the various links, including communications link **20**, connecting the elements can be wired or wireless links, or any combination thereof or any other known or later-developed element(s) that is capable of supplying and/or communicating data to and from the connected elements. The term module as used herein can refer to any known or later-developed hardware, software, or combination of hardware and software that is capable of performing the functionality associated with that element. Furthermore, as used herein, the term "transmitter" has the same meaning as the term "transmitting modem" or "transmitting transceiver" and the term "receiver" has the same meaning as "receiving modem" or "receiving transceiver."

FIG. **1** illustrates an exemplary embodiment of an impulse noise adaptation system **100** according to an exemplary embodiment of this invention. In particular, the system **100** comprises a receiving modem **200** and a transmitting modem **300**. The exemplary receiving modem **200** comprises a decoder/deinterleaver **210**, a bit error rate (BER) detection module **220**, a forward error correction and interleaving parameter (FIP) module **230**, an impulse noise length determination module **240**, an impulse noise period determination module **250**, an impulse noise parameter management module **260**, an impulse noise protection adaptation module **270**, a synchronization module **280**, a message module **290** and a controller and memory (not shown) all interconnected by a link **5**. The exemplary transmitting modem **300** comprises a management module **310**, a synchronization module **320**, a message module **330**, and may optionally include an impulse noise parameter management module **340**.

In operation, the exemplary communication system adapts the impulse noise parameters on-line by operating using a series of different FIP settings. For each FIP setting, the system can dynamically determine if the appropriate amount of impulse noise protection is being provided. Based on these determinations, the system can select a particular FIP setting for regular, i.e., Showtime, operation. As will be discussed in greater detail hereinafter, this impulse noise protection adaptation can be performed during Showtime and/or during initialization.

Impulse noise protection adaptation during Showtime includes the following exemplary steps. First, the DSL system, i.e., the transmitting and receiving modems, completes regular initialization and commences transmission and reception using a first FIP setting. For DSL systems, this first FIP setting is selected by the receiver **200** and is based on the minimum/maximum data rate, maximum latency, and minimum INP parameters as configured by, for example, the service provider via the management module **310**. A detailed explanation of this procedure can be seen in G.992.3.

The system will use this first FIP setting for a period of time T**1**. During this period, and in conjunction with the BER detection module **220**, the receiver **200** detects if bit errors have occurred using this first FIP setting for the decoding and deinterleaving performed by the decoder/deinterleaver **210**. For example, the receiver **200** can use a CRC to detect bit errors. If there are no bit errors, then the current INP setting is adequate and there is no need to modify the INP setting and Showtime communication can continue as normal.

However, if bit errors have been detected by the BER detection module **220**, an adjustment to the INP setting may be appropriate. For example, a service provider, a user, or the system can choose an updated INP setting. Since bit errors have been detected, the INP setting could be increased by an on-line modification to the FIP parameters. Specifically, the transmitter **300**, and for example the management module **310**, in response to an indication from the receiver **200** that bit errors have been detected, can send a message to the receiver **200** to initiate a change in the INP settings. The receiver **200**, in cooperation with the message module **290**, the FIP module **230**, the impulse noise parameter management module **260** and impulse noise protection adaptation module **270**, can return a message to the transmitter **300** that specifies a newly determined FIP setting that satisfies the new INP requirement.

The transmitter **300** and receiver **200** can then transition to the new INP setting by starting to use the new FIP parameters

for transmission and reception, respectively, at a synchronized point in time. This synchronization can be done in accordance with a number of exemplary methods that are discussed hereinafter.

Upon synchronization, the system **100** continues communication using the updated FIP settings for a second period of time T**2**. If the receiver detects that bit errors are occurring using this updated FIP setting during the decoding and deinterleaving performed by the decoder/deinterleaver **210** the steps can be repeated with the selection of another updated INP setting. However, if there are no bit errors detected by the receiver **200** during the time period T**2**, then the new INP setting is adequate and there is no need for further change at which point the INP adaptation procedure can end.

This Showtime-based INP adaptation process can be repeated as many times as necessary until an INP setting is obtained that provides the required impulse noise immunity and/or bit error rate.

One advantage of this technique is that the transition between different FIP settings can be accomplished without reinitializing the transceivers using the lengthy standard initialization procedure that is typically used in ADSL and VDSL systems. In contrast, the transition can occur without the standard initialization since the transition between FIP settings can be synchronized between the transmitter and the receiver such that the receiver **200** can determine when to start FEC decoding using the new FIP settings for K and R. As will be discussed hereinafter, this transition can be synchronized using a number of different exemplary methods.

The transition can also be accomplished without synchronization in which case the receiver **200** will determine when the new FIP settings are used by some alternative means. For example, the receiver could determine when the new FIP settings are being used by FEC decoding using both the old and updated FIP settings and determining which one is currently being utilized by the transmitter by determining with which FIP setting the codeword is correct. Other receiver functions such as CRCs, ATM HEC errors and the like could also be used.

This impulse noise protection adaptation procedure can be performed during regular steady-state transmission, i.e., Showtime in ADSL, using actual user data or, for example, idle ATM cells. This methodology can also be performed during a special impulse noise training period during which the system is not actually transmitting user data. For example, this impulse noise training period could utilize transmitted predefined pseudorandom bit streams or, for example, idle ATM cells or HDLC flags for determining an appropriate INP value.

The length of the time periods T**1**, T**2**, . . . can be controlled by, for example, the receiving modem **200**. The receiving modem **200** could control the length of these time periods by, for example, sending a message that specifies how long the transmitter should transmit using a particular FIP setting. This length can be defined, for example, in terms of the number of DMT symbols or the number of FEC codewords. For example, a message could indicate that 200 DMT symbols should be sent for all FIP settings or 300 FEC code words should be sent for all FIP settings. Alternately, the message can indicate a different number of DMT symbols or FEC code words for each FIP setting. This technique could further be used to aid in determining an appropriate INP setting by forwarding a predetermined number of DMT symbols at a first FIP value, followed by a second number of DMT symbols at a second FIP value, and so on. For each of these sets of DMT symbols and associated FIP values, the receiver could determine the bit error rate, with the cooperation of the BER detection module **220**, and then forward a message, with the cooperation of the message module **290**, to the transmitter **300** specifying which FIP setting provided the appropriate impulse noise protection.

Similarly, the transmitting modem **300** and receiving modem **200** could cooperate such that an optimum impulse noise protection value is converged upon. For example, the transmitting modem **300**, with the cooperation of the message module **330**, could forward a message to the receiving modem **200** specifying a first INP setting. If there are no bit errors, a message could be sent via the message module **290** to the transmitting modem **300** indicating that there are no bit errors and a lower INP value could be attempted. The impulse noise parameter management module **260** and FIP module **230** could then determine an appropriate lower INP setting and forward it to the transmitter **300**. As discussed above, since a lower INP value is inversely proportional to the user data rate, it is advantageous to optimize the INP value based on detected errors. The transmitting modem **300**, in cooperation with the message module **330**, could then send another message to the receiving modem **200** indicating that the lower INP value will be transitioned to at which point the procedure repeats itself through detection of bit errors in cooperation with the bit error rate detection module **220** and the decoder/deinterleaver **210**. This reduction in the INP parameters can continue until bit errors are detected at which point a message is sent, with the cooperation of the message module **290**, to the transmitting modem **300** indicating a higher INP value is required since bit errors were detected. Then, for example, based on an evaluation of a convergence of bit errors vs. impulse noise protection parameters, an optimum INP value can be determined and transitioned to by the receiver **300** and transmitter **200**. This procedure could also be used to increase the INP parameters in a similar fashion.

The length of the time periods T**1**, T**2**, . . . can also be controlled by the transmitter **300**. For example, the transmitter **300** could control the length of these time periods, by, for example, sending a message to the receiver **200** that specifies the length of time the transmitter will transmit using a particular FIP setting. This length could be defined in terms of the number of DMT symbols or, for example, the number of FEC codewords. The exemplary message could indicate that, for example, 200 DMT symbols would be sent for all FIP settings or 300 FEC codewords will be sent for all FIP settings. The message could also indicate a different number of DMT symbols or FEC codewords for each FIP setting. In general, the message could contain any type of information relating to how long the transmitter will be using a specific FIP setting(s).

The length of the time periods T**1**, T**2** . . . can also be controlled by, for example, a service provider or a user. For example, the service provider could configure through the management module **310** a minimum time X=10 seconds to be used for testing each FIP setting. The service provider could use the knowledge of the nature of the impulse noise, such as how often impulse noise event occurs, to determine the times. However, and in general, the length of the time periods could be configured to be any length of time as appropriate.

As discussed above, when a determination is made that there are bit errors and an increase in the INP setting is desirable, the receiving modem **200** can determine the new INP settings. However, it should be appreciated that the transmitting modem **300**, in cooperation with the impulse noise parameter management module **340** could also determine updated INP settings. For example, either modem could con-

tinually adapt the INP values as discussed above until no bit errors that are the result of impulse noise are detected by the BER detection module **220**.

As alluded to above, the receiver and transmitter can synchronize the modification of the FEC and interleaving parameters such that the both the transmitter and receiver start using the parameters at the same instant in time. This synchronization can be based on, for example, a synchronization using FEC codeword counters or a flag signal.

For synchronization using FEC codeword counters, the receiver **200** and transmitter **300** can synchronize the change in cooperation with the sync modules **280** and **320**, by counting the FEC codewords from the beginning of Showtime and the transition would occur when a specific FEC codeword counter value that is known by both the transmitter **300** and the receiver **200** is reached. Prior to the transition point, the transmitter **300** or receiver **200** in cooperation with the message module **290** and message module **330**, would send a message indicating the FEC codeword count value on which the FIP parameters will be updated. For example, the transmitting modem **300** can enter into Showtime and the synchronization module **320** commences counting the number of transmitted FEC codewords. For example, the first codeword transmitted has a count value of 0, the second transmitted codeword has a count value of 1 . . . . The counter can optionally be defined as having a finite length, for example, 0 to 1023 (10 bits) such that when the value of 1023 is reached, on the next FEC code word that is transmitted, the counter restarts at the value of 0.

Similarly, the receiving modem **200** upon entering Showtime starts a counter in cooperation with the synchronization module **280** that counts the number of received FEC codewords. The first received FEC codeword has a count value of 0, the second received FEC codeword to the count value of 1 . . . . As with the synchronization module **320**, the synchronization module **280** can have a counter with a finite length, for example 0-1023, such that when the value of 1023 is reached, on the next FEC codeword the counter restarts at 0.

At some point, for example, based on detected bit errors, the user, a service provider, or the like, it is determined that an updated FIP setting is needed. The receiving modem **200** can send a message, via the message module **290**, to the transmitting modem **300**, and in particular the message module **330** and impulse noise parameter management module **340**. The updated FIP setting can alternatively be sent from the transmitting modem to the receiving modem.

The synchronization module **280** and message module **290** then cooperate to send a message to the transmitting modem **300** specifying the FEC codeword counter value on which the new FIP settings are to be used for transmission and reception. Alternatively, the transmitting modem, in cooperation with the message module **330**, can send a message to the receiving modem indicating the FEC codeword counter value on which the FIP settings are to be used for transmission and reception. For example, the message can indicate that when the code word counter equals **501**, the new FIP setting will be used for transmission and reception.

When the transmitter FEC codeword counter equals the value indicated in the message, the synchronization module **220** instructs the transmitting modem **300** to transition to the new FIP settings. Similarly, when the synchronization module **280** in the receiving modem **200** counts the FEC codeword that equals the value indicated in the message, the receiving modem **200** transitions to using the new FIP settings for reception.

Synchronization can also be performed through the use of a flag signal (sync flag). For this exemplary embodiment, the receiving modem **200** and transmitting modem **300**, in cooperation with the synchronization module **280** and synchronization module **320**, synchronize the change in FIP settings using a flag or marker signal that is similar to that used in the ADSL2 G.992.3 ORL protocol. This protocol may be more desirable than using an FEC codeword counter because, for example, it has greater impulse noise immunity.

For synchronization using a flag signal, the receiver and transmitter would start using updated FEC and interleaving parameters on a pre-defined FEC codeword boundary following the sync flag. For example, while transmitting using a first INP setting, a determination is made by, for example, the BER detection module **220** that a new FIP setting is needed due to the presence of impulse noise on the line. This determination can be performed by the receiving modem, in cooperation with the FIP module **230**, the transmitting modem, a user, a service provider, or the like. The receiving modem **200**, in cooperation with the message module **290**, sends a message to the transmitting modem **300** indicating the new FIP settings to be used for transmission and reception. Alternatively, the transmitting modem, in cooperation with the message module **330**, prepares and sends a message to the receiving modem indicating the updated FIP settings to be used for transmission and reception.

The transmitting modem then sends a flag or marker signal to the receiving modem **200** indicating that the new FIP settings are to be used on a predetermined number of DMT symbols following the transmission of the flag or marker signal. For example, the flag signal could be an inverted sync symbol, or sync FLAG, as used in the ADSL2 G.992.3 OLR protocol. The transmitting modem **300** then starts using the new FIP settings for transmission on the predetermined number of DMT symbols following the transmission of the flag or marker signal. Similarly, the receiving modem starts using the new FIP settings for reception once the predetermined number of DMT symbols following the receipt of the flag or marker signal have been received.

EXAMPLE 1

On-Line INP Adaptation FIP Setting

This section describes an example of FIP settings for On-Line INP adaptation for DSL. In this example only the number of information bytes in a codeword (K) and the number of parity bytes in a codeword (R) are updated on-line. The Codeword Size (N) and Interleaver Depth (D) are not changed. This means that the latency (and interleaver memory size) and the line rate are not modified on-line. Since N=K+R this places restrictions on the allowed values for K and R.

1st Setting—{Approximate User Data Rate=3.968 Mbps, Line Rate=4.096 Mbps, N=128, K=124, R=4, S=1, D=64, Latency=16 msec, INP=1}

2nd Setting—{Approximate User Data Rate=3.840 Mbps, Line Rate=4.096 Mbps, N=128, K=120, R=8, S=1, D=64, Latency=16 msec, INP=2}

3nd Setting—{Approximate User Data Rate=3.584 Mbps, Line Rate=4.096 Mbps, N=128, K=112, R=16, S=1, D=64, Latency=16 msec, INP=4}

The On-line INP adaptation process is restricted to only modify the number of information bytes in a codeword (K) and the number of parity bytes in a codeword (R). The FEC Codeword Size (N=K+R) and Interleaver Depth (D) are not changed. This means that the latency (or interleaver memory size) and the line rate are not modified on-line. However the user data rate will change during the process since K is being modified. Also since the line rate and the FEC codeword size

are not modified, the S value does not change in the process. It is important to note that with these constraints, the On-line INP adaptation process can be done in as seamless manner (no bit errors and service interruption). This means provided that the modification if the FIP setting is restricted to K and R, the transition between FIP settings can be done in a seamless manner. This is the case because if the codeword size N and the interleaver depth D are not modified, the transition can happen without the problem of "interleaving memory flushing." Interleaver memory flushing is a well-known problem in which errors occur because interleaver and deinterleaver memory locations are overwritten due to on-line changes in the codeword size (N) and or interleaver depth (D).

EXAMPLE 2

On-Line INP Adaptation FIP Setting

This section describes an example of FIP settings for On-Line INP adaptation for DSL. In this example only the Code-word Size (N) and the number of parity bytes in a codeword (R) are updated on line. The number of information bytes in a codeword (K) and Interleaver Depth (D) are not changed and therefore the user data rate does not change. This means that the latency (and interleaver memory size) and the line rate are modified on-line. Since N=K+R this places restrictions on the allowed values for K and R.

1st Setting—{Approximate User Data Rate=3.968 Mbps, Line Rate=4.096 Mbps, N=128, K=124, R=4, S=1, D=64, Latency=16 msec, INP=1}

2nd Setting—{Approximate User Data Rate=3.968 Mbps, Line Rate=4.224 Mbps, N=132, K=124, R=8, S=1, D=64, Latency=16 msec, INP=2}

3nd Setting—{Approximate User Data Rate=3.968 Mbps, Line Rate=4.480 N=128, K=124, R=16, S=1, D=64, Latency=16 msec, INP=4}

In this example the Line Rate is modified on-line. For this reason it is necessary to also complete a rate adaptation process in order to complete this On-Line INP adaptation. A method for Seamless Rate Adaptation is described in U.S. Pat. No. 6,498,808.

While these examples restrict the changes to a subset of the FIP parameters, they can obviously be extended to cover any combination of the FIP parameters (N, K, R and D). For example, the value of D could also be modified in addition to the values of K, R and N. This could result in a change in the required interleaver memory and latency. In order to keep the memory and latency constant it is necessary to change the codeword size (N) accordingly when changing the interleaver depth (D). For example, if the interleaver depths is changed from D=64 to D=128, the Codeword size would have to be decreased by a factor of 2 so that overall latency is constant.

FIG. **2** illustrates an exemplary modified initialization state machine that includes the INPTraining state prior to Show-time. This state machine is based on the VDSL G.993.1 ITU standard. As defined in G.993.1, VTU-O is the VDSL Transceiver Unit at the Optical Network Unit (ONU) and VTU-R is the VDSL Transceiver Unit at the Remote terminal The Initialization state machine in FIG. **2** is an example of how INPTraining states could be included in a modified VDSL initialization procedure. While exemplary FIG. **1** includes the INPTraining state at a specific time in the initialization sequence, the INPTraining state can be included at any time during initialization provided that it is preceded by a state during which Showtime parameters are exchanged between the transceivers.

O-P-INPTrain

During the O-P-INPTrain State the VTU-O transmitter transmits DMT Symbols using the standard PMD, PMS-TC and TPS-TC SHOWTIME functions with parameters exchanged during the previous Exchange Phase. During this state, the TPS-TC transmits idle ATM cells, HDLC flags or 64/65 idle packets. SOC is inactive during this state.

This state is used by the VTU-R to determine the correct DS INP setting based on Impulse Noise conditions on the line. For example, the downstream CRC, FEC error detection, TPS-TC error detection capabilities, and other receiver functions can be used to determine whether the INP setting is adequate. The receiver can also use these receiver functions to determine the correct INP setting.

If the VTU-R determines that the current INP setting is not adequate, the VTU-R transmits the R-P-ISYNCHRO2 signal to indicate the need to transition back to the Exchange Phase in order to exchange new transmission parameters.

If the VTU-R determines that the current INP setting is not adequate, the VTU-R transmits the R-P-SYNCHRO2 signal to indicate that it is OK to transition to Showtime with the current transmission parameters.

R-P-INPTrain

During the R-P-INPTrain State the VTU-R transmitter transmits DMT Symbols using the standard PMD, PMS-TC and TPS-TC Showtime functions with parameters exchanged during the previous Exchange Phase. During this state, the TPS-TC transmits idle ATM cells, HDLS flags or 64/65 idle packets. SOC is inactive during this state.

This state is used by the VTU-O to determine the correct US INP setting based on Impulse Noise conditions on the line. For example, the upstream (US) CRC, FEC error detection, TPS-TC error detection capabilities, and other receiver functions can be used to determine whether the INP setting is adequate. The receiver can also use these receiver functions to determine the correct INP setting.

If the VTU-O determines that the current INP setting is not adequate, the VTU-O transmits the O-P-ISYNCHRO2 signal to indicate the need to transition back to the Exchange Phase in order to exchange new transmission parameters.

If the VTU-O determines that the current INP setting is not adequate, the VTU-O transmits the O-P-SYNCHRO2 signal to indicate that it is OK to transition to Showtime with the current transmission parameters.

O-P-SYNCHRO2

The O-P-SYNCHRO2 is the same as defined in the current VDSL1. As in VDSL1, the VTU-O transmitter enters Show-time after transmitting the O-P-SYNCHRO2 signal.

But, if the VTU-R has not also entered into Showtime, the VTU-O waits for receipt of the R-P-SYNCHRO2 or R-P-ISYNCHRO2. If the VTU-O receives the R-P-SYNCHRO2 it continues in Showtime. If the VTU-O receives the R-P-ISYNCHRO2, the VTU-O transmitter transitions back to the beginning of the O-P-MEDLEY state.

R-P-SYNCHRO2

The O-P-SYNCHRO2 is the same as defined in the current VDSL1. As in VDSL1, the VTU-R transmitter enters Show-time after transmitting the R-P-SYNCHRO2 signal.

But, if the VTU-O has not also entered into Showtime, the VTU-R waits for receipt of the O-P-SYNCHRO2 or O-P-ISYNCHRO2. If the VTU-R receives the O-P-SYNCHRO2 it continues in Showtime. If the VTU-R receives the O-P-ISYNCHRO2, the VTU-R transmitter transitions back to the beginning of the R-P-MEDLEY state.

O-P-ISYNCHRO2

The O-P-ISYNCHRO2 is phase-inverted version of the O-P-SYNCHRO2, i.e., a subcarrier-by-subcarrier 180

degrees phase reversal. The VTU-O transmitter transitions to the beginning of the O-P-MEDLEY state after transmitting the O-P-ISYNCHRO2 signal.

R-P-ISYNCHRO2

The R-P-ISYNCHRO2 is phase-inverted version of the R-P-SYNCHRO2, i.e., a subcarrier-by-subcarrier 180 degrees phase reversal. The VTU-R transmitter transitions to the beginning of the R-P-MEDLEY state after transmitting the R-P-ISYNCHRO2 signal

Exemplary Overview State Transition Rules Based on SYNCHRO2 and the ISYNCHRO2 signals:

If either the VTU-O or the VTU-R transmits the ISYNCHRO2 signal then both VTU-R and VTU-O transition back to beginning of the MEDLEY state.

If both the VTU-O and the VTU-R transmit the SYNCHRO2 signal then both the VTU-R and the VTU-O transition into Showtime.

There are several important points regarding this exemplary embodiment. First, the receiver can measure the efficiency of the plurality of INP settings without completing a new initialization procedure such as is used in ADSL and VDSL systems. Second, the length of the time of the O-P-INPTrain and R-P-INPTrain states can be controlled by the VTU-R and VTU-O respectively. In this way the receivers have adequate time to determine if the current INP setting is correct. In order to accomplish this, prior to entering the R-P-INPTrain state, the VTU-O can transmit a message to the VTU-R indicating the minimum length of the R-P-INPTrain state. Likewise, prior to entering the O-P-INPTrain state, the VTU-R can transmit a message to the VTU-O indicating the minimum length of the O-P-INPTrain state. For example, the message could indicate that a minimum of 20000 DMT symbols should be sent during the O-P-INPTrain state. Additionally, the length of the time of the O-P-INPTrain and R-P-INPTrain states could be set by the DSL service provider in order to make sure that the initialization does not take too long or because the service provider may have some knowledge of the statistics of the impulse noise which require setting the length of the INPTrain states. In this exemplary case a message could be sent from the VTU-O to the VTU-R indicating the minimum and/or maximum length of the O-P-INPTrain and/or the R-P-INPTrain states. For example, the message could indicate that a minimum of 20000 DMT symbols should be sent during the R-P-INPTrain state. Also, for example, the message could indicate that a maximum of 40000 DMT symbols should be sent during the R-P-INPTrain state.

The length of the time of the O-P-INPTrain and R-P-INPTrain states could also be controlled by the VTU-O and VTU-R respectively. In this case, the transmitters will have control of the state lengths. In order to accomplish this, prior to entering the R-P-INPTrain state, the VTU-R can transmit a message to the VTU-O indicating the minimum length of the R-P-INPTrain state. Likewise, prior to entering the O-P-INPTrain state, the VTU-O can transmit a message to the VTU-R indicating the minimum length of the O-P-INPTrain state. For example, the message could indicate that a minimum of 20000 DMT symbols should be sent during the O-P-INPTrain state.

As discussed above, another exemplary aspect of this invention relates to determining the length and/or repetition period of impulse noise events in order to select an appropriate INP setting.

The INP length can be determined using any one of a plurality of metrics. For example, the INP length can be determined based on one or more of:

1) The length of the impulse in time
2) The number of received bits that are affected by the impulse noise
3) The number of received ATM cells that are affected by the impulse noise
4) The number of 64/65 packets that are affected by the impulse noise
5) The number of received DMT symbols that are affected by the impulse noise
6) The number of FEC codewords that are affected by the impulse noise

As an example, assume that length of the impulse noise is 700 microseconds (Example 1). At a data rate of 1 Mbps this could correspond to an impulse noise length of 700 bits (Example 2) assuming that all impulse noise was high enough to affect all 700 bits in the 700 microsecond period. This also could correspond to a impulse noise length of 700/(53*8) =1.65 ATM cells since there are 53 bytes in a ATM cell (Example 3). This also could correspond to an impulse noise length of 700/(65*8)=1.35 64/65 packets since there are 65 bytes in a 64/65 packet (Example 4). This also could correspond to an impulse noise length of 700/(250)=2.8 DMT symbols (INP=2.8) assuming the DMT symbol rate is 4 kHz (250 microseconds DMT symbol length) (Example 5).

As an example, the determination of the INP length with the number of received bits that are affected by impulse noise can be performed in accordance with the following procedure. Initially, the transmitting modem **300** transmits data using at least one of the Showtime functions. In accordance with a first exemplary embodiment, at least the bit allocation table is used. In addition, or alternatively, the trellis coder, framer, and TPS-TC functions may also be used. Additionally, or alternatively still, the interleaving and FEC may also be used.

The receiving modem **200** receives data using at least one of the Showtime functions, such as the bit allocation table as discussed above. Similarly, the trellis coder, framer, TPS-TC and/or interleaving and FEC can be used.

The transmitter **300** then transmits a predefined bit pattern that is used for determining or measuring the impulse noise length based on detected erroneous bits. The receiving modem **200** compares, with the assistance of the impulse noise length determination module **240**, the predefined bit pattern to the received bit pattern in order to detect bit errors. Since impulse noise events typically cause a burst of errors in a bit stream, the receiving modem **200** determines the length of the impulse noise event by detecting and determining the length of the error burst.

Once the receiver **200** determines the length of the impulse noise, the receiving modem **200**, in cooperation with the message module **290**, sends a message to the transmitter **300** that indicates the determined length of the impulse noise.

In accordance with an exemplary embodiment, the FEC correction capability and interleaving is turned off when trying to determine the length of the impulse noise, e.g., R=0 and D=1. Disabling the FEC and interleaving is beneficial when trying to determine the length of the impulse noise based on affected bits, affected code words, or affected packets. This is the case because if the FEC/interleaving is enabled, the impulse event can be spread over a large time period which makes it more difficult to determine the length of the original impulse.

The exemplary methodology discussed above can also be used to determine the length of the impulse event using other metrics. For example, a predefined bit pattern could be used in the payload of the ATM cells or the 64/65 packets. Idle packets or cells, which carry a predefined pattern, could also be used. In these cases, the receiver would compare the received

data to the predefined data to determine the length of the impulse or to determine if an INP setting is adequate. Alternatively, the CRC of the ATM cell or 64/65 packet could be used to determine the length of the impulse noise. This would provide a courser measurement of the impulse noise length since it would be an integer number of packets or cells. In this example, a 700 bit impulse would cause CRC errors in two ATM cells so the length of the impulse noise would be two ATM cells, as opposed to the more precise measurement of 1.64 above. Likewise, in this example, a 700 bit impulse would cause CRC errors in two 64/65 packets so the length of the impulse noise would be two packets, as opposed to the more precise measure of 1.35 above.

Likewise, a predefined bit pattern could also be used to modulate the carriers in the DMT symbols so that the receiver would know what DMT symbols were transmitted. In this case, the receiver **200** would determine how many DMT symbols were corrupted by comparing the received signal with a known transmitted signal.

The exemplary techniques used to determine the length of the impulse noise event could also be extended to determine the repetition rate of the impulse noise event in cooperation with the impulse noise period determination module **250**. In order to determine the repetition period of an impulse noise event, the receiver **200** detects the impulse noise event as discussed above and then determines how often they occur. For example, periodic impulse noise due to AC power lines occur at 120 Hz reception rates or approximately every 8 ms. The receiver **200** could, for example, also store information about past impulse noise events and compare detected impulse noise events to historical events. The impulse noise period determination module **250** could then determine which events of a similar duration are occurring at what interval. This information could then be used in determining an appropriate INP setting.

Once the receiver **200** determines the (maximum) length of the impulse and/or the repetition period of the impulse, the information, with the cooperation of the message module **290** can be sent to the transmitting modem. For example, when the receiving modem **200** determines the (maximum) length of the impulse and/or the repetition period of the impulse, the impulse noise period determination module **250**, in cooperation with the message module **290** can forward information to the transmitting modem that quantifies this period. The transmitting modem **300** could provide this information to, for example, the management module **310**, that would allow, for example, an operator or service provider to configure the modems. For example, based on the period information contained in the message, the operator may configure the modems to different INP values, data rates, latency, or the like.

The receiver **200** could also test a specific INP setting by detecting how many received bits are errored in a specific time period. For example, if the specific INP setting enables the correction of 100 bits in an 8 msec. time period then the receiver **200** could detect how many bits are errored in a sliding 8 msec. window. If less than 100 bits are detected in error in the 8 ms sliding window, then the INP setting is adequate.

If more than 100 bits are detected in error in a sliding window, then the INP setting is not adequate, and the FEC/interleaving needs to be changed to provide more error correction capability.

Likewise, instead of using the received number of bits that are effected by the impulse noise, the receiver could test a specific INP setting by detecting how many received ATM cells, 64/65 packets, DMT symbols, and/or FEC corrections are affected in a specific time period.

FIG. **3** outlines an exemplary method for performing impulse noise protection adaptation during Showtime according to this invention. In particular, control begins in step S**300** and continues to step S**310**. In step S**310**, traditional DSL initialization occurs. Next, in step S**320**, Showtime is entered between the two modems using the first FIP setting that was determined during the initialization in step S**310**. Then, in step S**330**, a determination is made whether bit errors are occurring using the first FIP setting. If bit errors are not occurring, control continues to step S**340** where the control sequence ends. Otherwise, control jumps to step S**350**.

In step S**350**, a determination is made that an increase of the INP setting is required that requires modification of the FIP parameters. Next, in step S**360**, updated INP parameter is determined and a message forwarded to the receiver specifying the new INP setting. Then, in step S**370**, the receiver forwards to the transmitter updated FIP parameters for the new impulse noise protection requirements. Control then continues to step S**380**.

In step S**380**, the transmitter and receiver transition to using the updated INP parameters at a synchronization point. Next, in step S**390** Showtime operation continues. Control then continues back to step S**330**.

FIG. **4** outlines an exemplary method for receiver optimized impulse noise protection adaptation during Showtime. In particular, control begins in step S**400** and continues to step S**410**. In step S**410**, the DSL system completes regular initialization In particular, control begins in step S**400** and continues to step S**410**. In step S**410**, the DSL system completes startup initialization and continues into Showtime in step S**420** using a first FIP setting. Control then continues to step S**430** where a determination is made whether bit errors are occurring using the first FIP setting. If bit errors are not occurring, control continues to step S**440** where the control sequence ends.

Otherwise, control jumps to step S**450** where the receiver increases the impulse noise protection by modifying the FIP parameters. Next, in step S**460**, a synchronization point is determined between the transmitter and receiver, and when the synchronization point is reached both the transmitter and the receiver transition to the updated FIP setting in step S**470** and Showtime communications continue and control returns back to step S**430**.

FIG. **5** illustrates an exemplary method for synchronization of the modified FEC and interleaving parameters according to this invention. In particular, control begins in step S**500** and continues to step S**510**. In step S**510**, the transmitter enters Showtime and counts the number of transmitted FEC codewords. Next, in step S**520**, the receiver enters Showtime and counts the number of received FEC codewords. Then, in step S**530**, after a determination is made that an updated FIP setting is needed, the receiving modem sends a message to the transmitting modem indicating a new FIP setting that is to be used for transmitting and reception or, alternatively, the transmitting modem sends a message to the receiving modem indicating the new FIP setting to be used for transmission and reception. Control then continues to step S**540**.

In step S**540**, a message with the FEC codeword counter value on which the new FIP values are to be used is exchanged. Next, in step S**550**, a determination is made whether the counter value has been reached at the transmitter. If the counter value has not been reached, the next codeword is counted in step S**560** and control continues back to step S**550**.

Otherwise, if the counter value has been reached, control jumps to step S570. In step S570, the transmitter transitions to the new FIP setting. Next, in step S580, a determination is made whether the counter value has been reached at the receiving modem. If the counter value has not been reached, the next received FEC codeword is counted in step S585 and control continues back to step S580. However, when the counter value has been reached in the receiving modem, control jumps to step S590 where the receiving modem switches to the new FIP value. Control then continues to step S595 where the modems continue Showtime communication and control continues to step S597 where the control sequence ends.

FIG. 6 illustrates an exemplary method of synchronization using a flag signal according to this invention. In particular, control begins in step S600 and continues to step S610. In step S610, the modems enter Showtime using the first FIP parameters. Next, in step S620, a message is exchanged indicating the new FIP settings. Then, in step S630, the transmitter forwards to the receiver a flag signal indicating when the new FIP settings are to be used.

At step S640, and at a predefined change time following the transmission of the flag signal, the transmitter begins transmission using the new FIP parameters. Next, at step S650, at the predefined change time following the reception of the flag signal, the receiver commences reception utilizing the new FIP parameters. Control then continues to step S660 where Showtime communication continues with the control sequence ending at step S670.

FIG. 7 illustrates an exemplary method of impulse noise length and period determination. In particular, control begins in step S700 and continues to step S710. In step S710, the transmitter transmits data using at least one Showtime function. Next, in step S720, the receiver receives data using at least one Showtime function. Then, in step S730, the transmitter transmits predefined information to the receiver. Control then continues to step S740.

In step S740, the receiver receives the predefined information from the transmitter. Next, in step S750, the receiver compares the received predefined information to the predefined information and determines the differences (i.e., errors) between the two. Then, in step S760, and based on the detected errors, the length of the burst error is determined Next, in step S770, a message is forwarded to the transmitter indicating the length of the impulse noise event. Control then continues to step S780 where a determination is made whether the period of the impulse noise event is also to be determined If the period is not to be determined, control continues to step S790 where the control sequence ends. Otherwise, control jumps to step S800.

In step S800, and once the length of the impulse noise event is know, the receiver detects how often the impulse noise events occur. For example, historical information regarding the length and timing of previous impulse noise events can be stored in a memory (not shown). Then, a comparison can be made with the aid of a processor (not shown) to compare an impulse noise event to the historical information to determine the period of repetition (if any) of similar impulse noise events and, for example, a message indicating the period as well as the timing forwarded to, for example, another transceiver, the CO, or in general any destination as appropriate. Thus, in a similar manner, this information can be forwarded in step S810 to, for example, the transmitter in a message specifying the repetition frequency of the impulse noise event. Control then continues to step S820 where the control sequence ends.

The above-described system can be implemented on wired and/or wireless telecommunications device(s), such a modem, a multicarrier modem, a DSL modem, an ADSL modem, an xDSL modem, a VDSL modem, a linecard, test equipment, a multicarrier transceiver, a wired and/or wireless wide/local area network system, a satellite communication system, a modem equipped with diagnostic capabilities, or the like, or on a separate programmed general purpose computer having a communications device.

Additionally, the systems, methods and protocols of this invention can be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, modem, transmitter/receiver, or the like. In general, any device capable of implementing a state machine that is in turn capable of implementing the methodology illustrated herein can be used to implement the various communication methods, protocols and techniques according to this invention.

Furthermore, the disclosed methods may be readily implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed system may be implemented partially or fully in hardware using standard logic circuits or VLSI design. Whether software or hardware is used to implement the systems in accordance with this invention is dependent on the speed and/or efficiency requirements of the system, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The communication systems, methods and protocols illustrated herein however can be readily implemented in hardware and/or software, or any means, using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods may be readily implemented in software, that can be stored on a storage medium, and executed on programmed general-purpose computer, a special purpose computer, a microprocessor, or the like. In these instances, the systems and methods of this invention can be implemented as a program embedded on personal computer such as JAVA® or CGI script, as a resource residing on a server or computer workstation, as a routine embedded in a dedicated communication system or system component, or the like. The system can also be implemented by physically incorporating the system and/or method into a software and/or hardware system, such as the hardware and software systems of a communications transceiver.

It is therefore apparent that there has been provided, in accordance with the present invention, systems and methods for impulse noise adaptation. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable arts. Accordingly, it is intended to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and scope of this invention.

The invention claimed is:

1. In a transceiver, a method of adapting forward error correction and interleaver parameter (FIP) settings of the transceiver during steady-state communication or initialization comprising:

transmitting, by the transceiver, a signal using a first FIP setting;

transmitting, by the transceiver, a flag signal; and

switching, by the transceiver, to using, for transmitting, a second FIP setting following transmission of the flag signal,

wherein:

the first FIP setting comprises at least one first FIP value,

the second FIP setting comprises at least one second FIP value, different than the first FIP value, and

the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

2. The method of claim **1**, wherein a first forward error correction parameter value of the first FIP setting is different than a second forward error correction parameter value of the second FIP setting.

3. The method of claim **1**, wherein a first interleaver parameter value of the first FIP setting is different than a second interleaver parameter value of the second FIP setting.

4. The method of claim **1**, wherein the adapting of the FIP settings is based on a service provider configuration.

5. The method of claim **1**, further comprising transmitting the flag signal on a telephone line that experiences impulse noise from external sources including one or more of AM radio, HAM radio and AC power lines.

6. The method of claim **1**, wherein the method is performed in a linecard that includes a management interface that is used by an operator or service provider to configure a service.

7. The method of claim **1**, wherein the method is performed in a Customer Premises Equipment (CPE) that includes a management interface that is used by an operator, a service provider or service user.

8. An apparatus configurable to adapt forward error correction and interleaver parameter (FIP) settings during steady-state communication or initialization comprising:

a transceiver, including a processor, configurable to:

transmit a signal using a first FIP setting,

transmit a flag signal, and

switch to using for transmission, a second FIP setting following transmission of the flag signal,

wherein:

the first FIP setting comprises at least one first FIP value,

the second FIP setting comprises at least one second FIP value, different than the first FIP value, and

the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

9. The apparatus of claim **8**, wherein a first forward error correction parameter value of the first FIP setting is different than a second forward error correction parameter value of the second FIP setting.

10. The apparatus of claim **8**, wherein a first interleaver parameter value of the first FIP setting is different than a second interleaver parameter value of the second FIP setting.

11. The apparatus of claim **8**, wherein the adapting of the FIP settings is based on a service provider configuration.

12. The apparatus of claim **8**, wherein the transceiver is operable to transmit the flag signal on a telephone line that experiences impulse noise from external sources including one or more of AM radio, HAM radio and AC power lines.

13. The apparatus of claim **8**, wherein the transceiver is located in a linecard that includes a management interface that is usable by an operator or service provider to configure a service.

14. The apparatus of claim **8**, wherein the transceiver is located in a Customer Premises Equipment (CPE) that includes a management interface that is usable by an operator, a service provider or service user.

15. The apparatus of claim **8**, wherein the transceiver includes at least one digital signal processor.

16. The apparatus of claim **8**, wherein the transceiver includes at least one ASIC.

17. In a transceiver, a method of adapting forward error correction and interleaver parameter (FIP) settings of the transceiver during steady-state communication or initialization comprising:

receiving, by the transceiver, a signal using a first FIP setting;

receiving, by the transceiver, a flag signal; and

switching, by the transceiver, to using, for receiving, a second FIP setting following reception of the received flag signal,

wherein:

the first FIP setting comprises at least one FIP value,

the second FIP setting comprises at least one second FIP value, different than the first FIP value, and

the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

18. The method of claim **17**, wherein a first forward error correction parameter value of the first FIP setting is different than a second forward error correction parameter value of the second FIP setting.

19. The method of claim **17**, wherein a first interleaver parameter value of the first FIP setting is different than a second interleaver parameter value of the second FIP setting.

20. The method of claim **17**, wherein the adapting of the FIP settings is based on a service provider configuration.

21. The method of claim **17**, further comprising receiving the flag signal over a telephone line that experiences impulse noise from external sources including one or more of AM radio, HAM radio and AC power lines.

22. The method of claim **17**, wherein the method is performed in a linecard that includes a management interface that is used by an operator or service provider to configure a service.

23. The method of claim **17**, wherein the method is performed in a Customer Premises Equipment (CPE) that includes a management interface that is used by an operator, a service provider or service user.

24. An apparatus configurable to adapt forward error correction and interleaver parameter (FIP) settings during steady-state communication or initialization comprising:

a transceiver, including a processor, configurable to:

receive a signal using a first FIP setting,

receive a flag signal, and

switch to using for reception, a second FIP setting following reception of the flag signal,

wherein:

the first FIP setting comprises at least one first FIP value,

the second FIP setting comprises at least one second FIP value, different than the first FIP value, and

the switching occurs on a pre-defined forward error correction codeword boundary following the flag signal.

25. The apparatus of claim **24**, wherein a first forward error correction parameter value of the first FIP setting is different than a second forward error correction parameter value of the second FIP setting.

26. The apparatus of claim **24**, wherein a first interleaver parameter value of the first FIP setting is different than a second interleaver parameter value of the second FIP setting.

27. The apparatus of claim **24**, wherein the adapting of the FIP settings is based on a service provider configuration.

28. The apparatus of claim **24**, wherein the transceiver is operable to receive the flag signal over a telephone line that

experiences impulse noise from external sources including one or more of AM radio, HAM radio and AC power lines.

29. The apparatus of claim **24**, wherein the transceiver is located in a linecard that includes a management interface that is usable by an operator or service provider to configure a service.

30. The apparatus of claim **24**, wherein the transceiver is located in a Customer Premises Equipment (CPE) that includes a management interface that is usable by an operator, a service provider or service user.

31. The apparatus of claim **24**, wherein the transceiver includes at least one digital signal processor.

32. The apparatus of claim **24**, wherein the transceiver includes at least one ASIC.

* * * * *

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(12) **United States Patent**
Tzannes

(10) **Patent No.: US 8,468,411 B2**
(45) **Date of Patent: *Jun. 18, 2013**

(54) **PACKET RETRANSMISSION**

(75) Inventor: **Marcos C. Tzannes**, Orinda, CA (US)

(73) Assignee: **TQ Delta, LLC**, Austin, TX (US)

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This patent is subject to a terminal disclaimer.

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G08C 25/02 (2006.01)
H04L 1/18 (2006.01)

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USPC **714/748**; 375/130

(58) **Field of Classification Search**
USPC 714/748; 375/130
See application file for complete search history.

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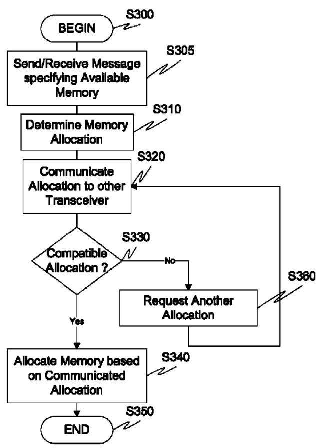
Primary Examiner — Sam Rizk

(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross, PC

(57) **ABSTRACT**

Through the identification of different packet-types, packets can be handled based on an assigned packet handling identifier. This identifier can, for example, enable forwarding of latency-sensitive packets without delay and allow error-sensitive packets to be stored for possible retransmission. In another embodiment, and optionally in conjunction with retransmission protocols including a packet handling identifier, a memory used for retransmission of packets can be shared with other transceiver functionality such as, coding, decoding, interleaving, deinterleaving, error correction, and the like.

25 Claims, 4 Drawing Sheets



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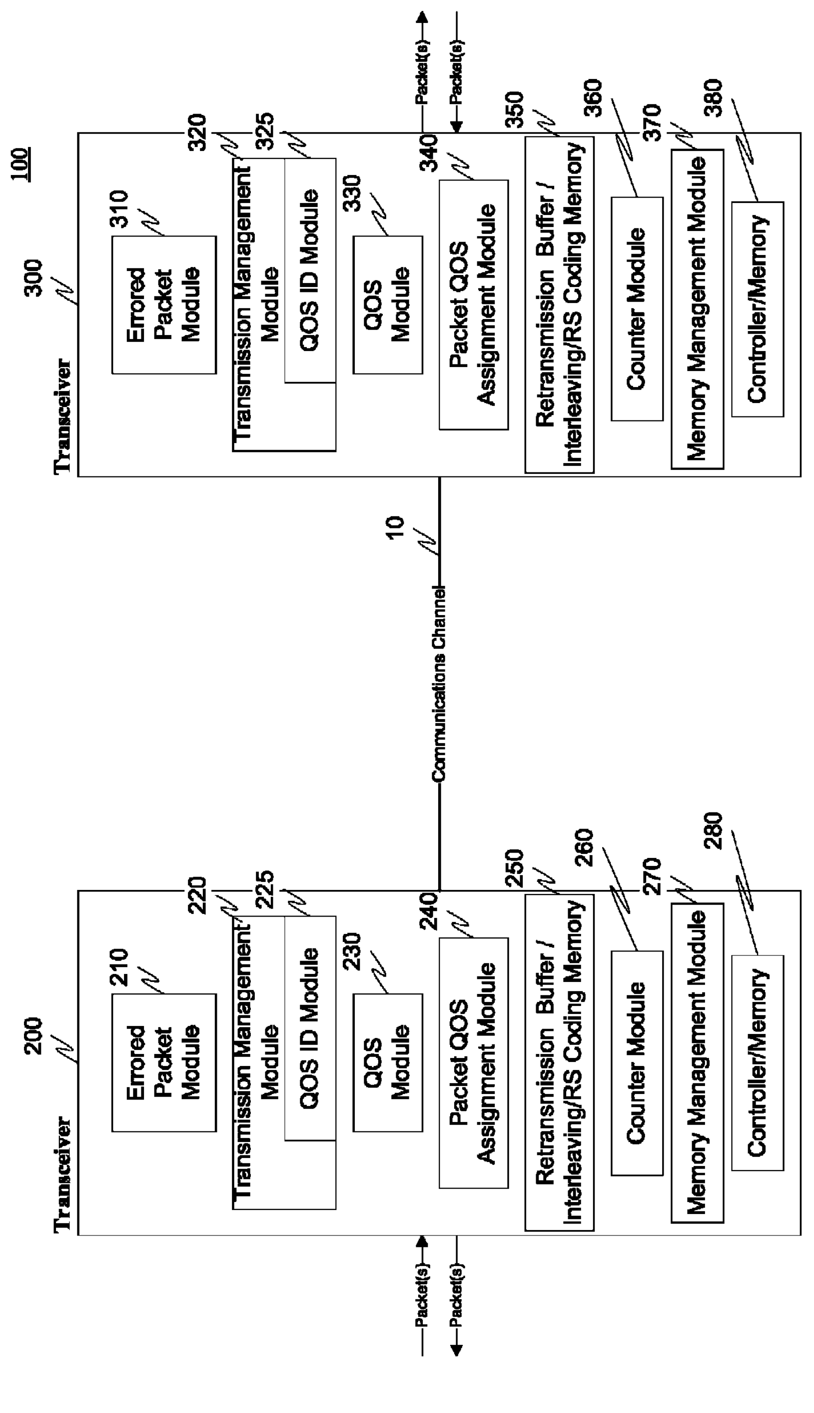
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Transceiver
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Errored Packet Module
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Transmission Management Module
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QOS ID Module
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QOS Module
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Packet QOS Assignment Module
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Retransmission Buffer / Interleaving/RS Coding Memory
360
Counter Module
370
Memory Management Module
380
Controller/Memory
Packet(s)
Packet(s)
10
Communications Channel
Transceiver
200
210
Errored Packet Module
220
Transmission Management Module
225
QOS ID Module
230
QOS Module
240
Packet QOS Assignment Module
250
Retransmission Buffer / Interleaving/RS Coding Memory
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Counter Module
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Memory Management Module
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Controller/Memory
Packet(s)
Packet(s)

Fig. 1

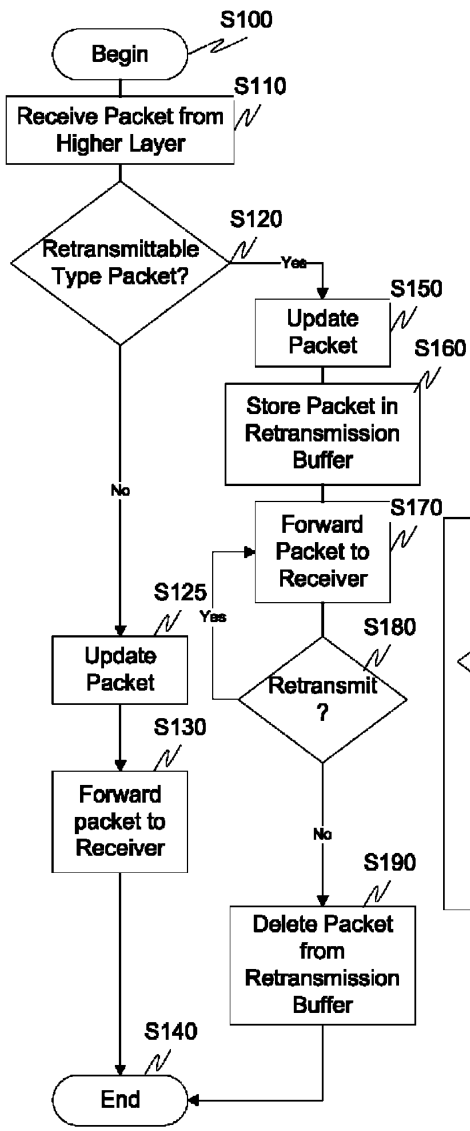

Fig. 2

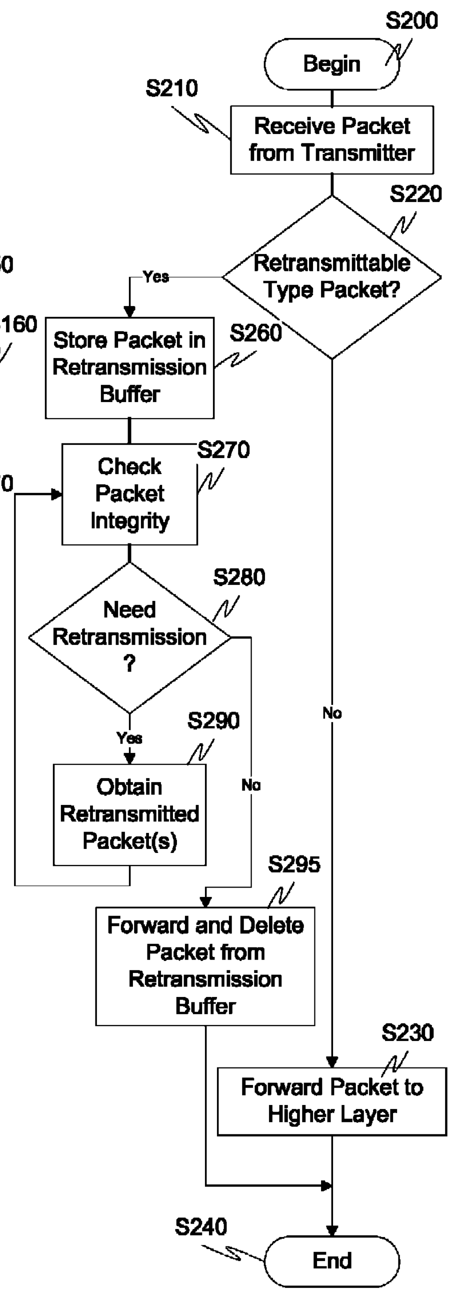

Fig. 3

TQD_TX-00043994

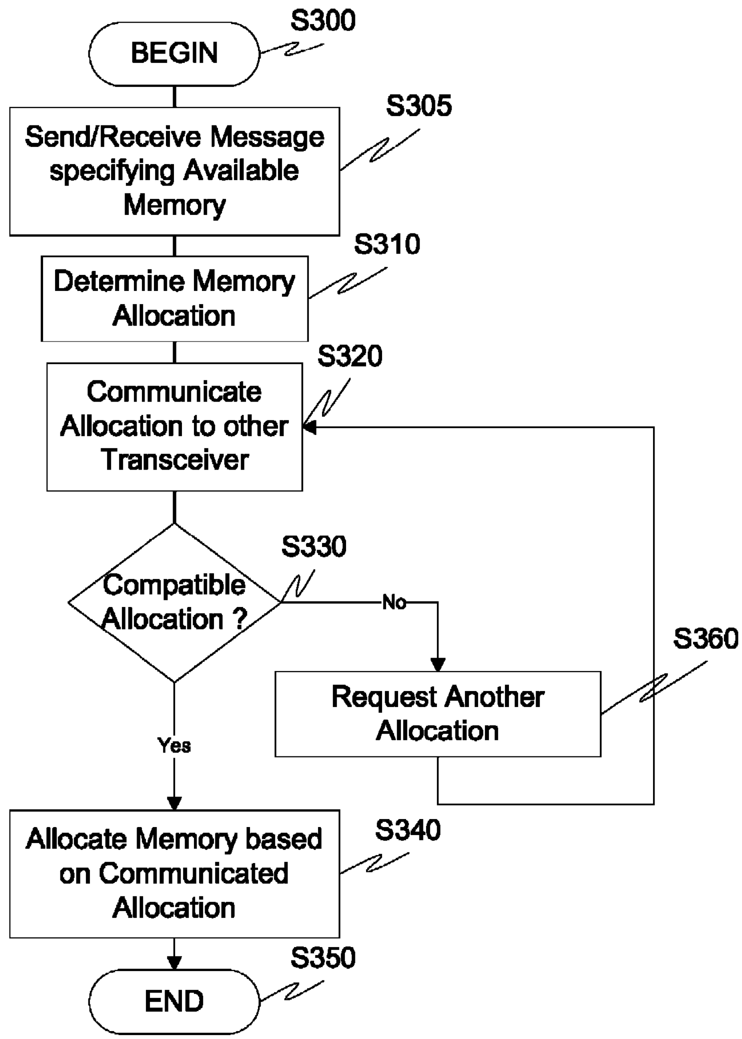
BEGIN
S300
Send/Receive Message specifying Available Memory
S305
Determine Memory Allocation
S310
Communicate Allocation to other Transceiver
S320
Compatible Allocation ?
S330
No
Yes
Request Another Allocation
S360
Allocate Memory based on Communicated Allocation
S340
END
S350

Fig. 4

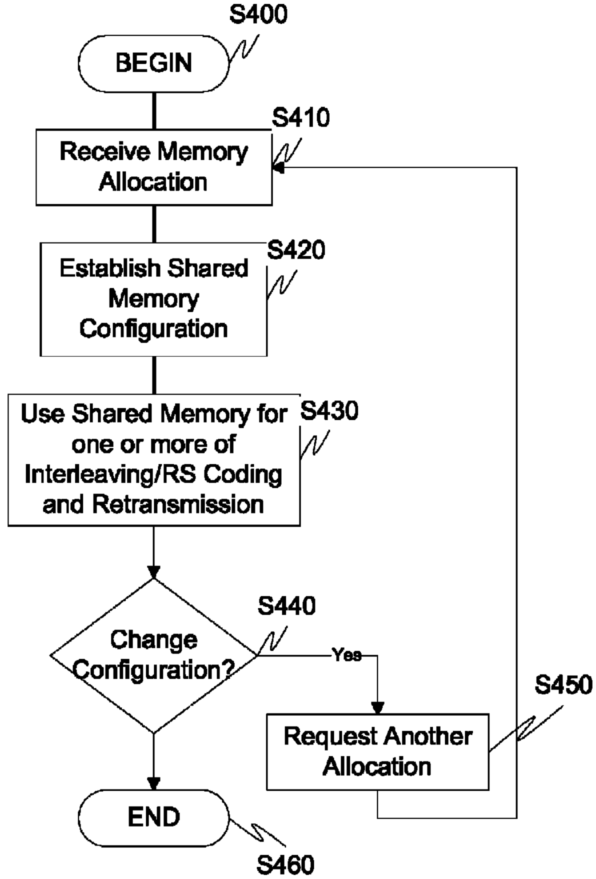
S400
BEGIN
S410
Receive Memory Allocation
S420
Establish Shared Memory Configuration
S430
Use Shared Memory for one or more of Interleaving/RS Coding and Retransmission
S440
Change Configuration?
Yes
S450
Request Another Allocation
END
S460

Fig. 5

PACKET RETRANSMISSION

RELATED APPLICATION DATA

This application is a Continuation of U.S. patent application Ser. No. 12/760,728, filed Apr. 15, 2010, which is a Divisional of U.S. patent application Ser. No. 12/295,828, filed Oct. 2, 2008, now U.S. Pat. No. 8,335,956 which is a national stage application under 35 U.S.C. 371 of PCT Application No. PCT/US2007/066522 having an international filing date of Apr. 12, 2007, which designated the United States, which PCT application claims the benefit of and priority under 35 U.S.C. §119(e) to U.S. Patent Application Nos. 60/792,236, filed Apr. 12, 2006, entitled "xDSL Packet Retransmission Mechanism," and 60/849,650, filed Oct. 5, 2006, entitled "xDSL Packet Retransmission Mechanism with Examples," each of which are incorporated herein by reference in their entirety.

BACKGROUND

Field of the Invention

This invention generally relates to communication systems. More specifically, an exemplary embodiment of this invention relates to retransmission of packets in a communication environment. An exemplary embodiment of this invention also relates to memory sharing between transmission functions and other transceiver functions.

SUMMARY

Exemplary aspects of the invention relate to handling of packets and the assignment of a packet handling identifier. Exemplary aspects relate to sharing of resources between retransmitted packets and other transceiver functions. In addition, exemplary aspects relate to sharing of resources between packets associated with the packet handling identifier and other transceiver functions.

More specifically, aspects of the invention relate to assigning a packet handling identifier to one or more packets. Based on the packet handling identifier, a packet can either be, for example, forwarded directly to another communication device (or layer) or, alternatively, held for possible retransmission protocols. For example, packets received from, for example, a higher-layer of a communication device, can be designated to have a specific packet handling identifier, such as a Quality of Service (QOS) level. The QOS level of a packet indicates the importance of certain service metrics (or characteristics) of one or more packets.

Two exemplary QOS metrics are delay (or latency) and Packet Error Rate (PER). While these two metrics are used for illustrative purposes herein, it should be appreciated that other metrics can also be used with this invention. For example, other QOS metrics could include one or more of a Bit Error Rate (BER), data rate, delay variation (or jitter), packet loss rate, time between error events (TBE), or the like.

As an example, in the case where the two QOS metrics are latency and PER, packets containing, for example, video information (such as IPTV) may have the requirement for a very low packet error rate but can often tolerate higher delay. In contrast, voice or data (e.g., gaming) traffic may have very low latency requirements but can tolerate a higher packet error rate. For this particular example, the video packets could be designated as "low-PER" QOS packets and the voice or data packets could be designated as "low-latency" QOS packets. For example, a specific QOS identifier could be assigned

to the low-latency packets while a different QOS identifier could be assigned to the low-PER packets. The low-latency packets could be forwarded directly to another transceiver, or a higher layer, while the low-PER packets can be stored in a retransmission buffer, e.g., memory, that can be used to reduce packet error.

As mentioned above, exemplary aspects also relate to sharing of resources between a retransmission function and other transceiver functions.

The exemplary systems and methods of this invention can utilize memory, such as a retransmission buffer, for the storing of packets for retransmission functions. Since other transceiver functions may also require memory to perform certain functionality, an exemplary aspect of this invention also relates to sharing the memory for retransmission functions with the memory required for other transceiver functions. For example, memory can be dynamically allocated based on configuration settings or noise conditions and, for example, the memory divided between one or more of interleaving/deinterleaving, RS Coding/Decoding functionality and the functionality used retransmission.

Aspects of the invention thus relate to identification of one or more packets.

Additional aspects of the invention relate to identifying one or more packets that can be retransmitted.

Still further aspects of the invention relate to identifying one or more packets that should not be retransmitted.

Aspects of the invention also relate to retransmission of one or more of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-data frame, a PTM-TC codeword, and RS codeword and a DMT symbols.

Still further aspects of the invention relate to appending an identifier to a packet.

Still further aspects of the invention relate to appending a sequence identifier to at least one packet.

Aspects of the invention also relate to routing one or more packets based on a packet handling identifier.

Aspects of the invention also relate to retransmitting a packet.

Aspects of the invention further relate to retransmit a packet based on a retransmission request.

Still further aspects of the invention relate to sharing memory between a retransmission function and one or more of an interleaver, deinterleaver, coder, decoder and other transceiver functionalities.

Other more specific aspects of the invention relate to sharing memory between a retransmission buffer (or memory) and interleaving/deinterleaving and/or coding/decoding functionality.

Additional exemplary, non-limiting aspects of the invention are:

1. A method of packet retransmission comprising:
   transmitting or receiving a plurality of packets;
   identifying at least one packet of the plurality of packets as a packet that should not be retransmitted.

2. The method of aspect 1, wherein the packet is any grouping of bytes.

3. The method of aspect 1, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

4. The method of aspect 1, wherein a bit field comprising a sequence identifier (SID) is appended to each packet.

5. The method of aspect 4, wherein the identifying step comprises using a special value for a sequence identifier (SID).

6. The method of aspect 4, wherein the appended bit field comprises a dedicated CRC.

7. The method of aspect 1, wherein the at least one packet is not stored for retransmission.

8. The method of aspect 1, wherein the at least one packet is passed immediately to a high layer.

9. A packet retransmission module capable of transmitting or receiving a plurality of packets and capable of identifying at least one packet of the plurality of packets as a packet that should not be retransmitted.

10. The module of aspect 9, wherein the packet is any grouping of bytes.

11. The module of aspect 9, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

12. The module of aspect 9, wherein the module is capable of appending a bit field comprising a sequence identifier (SID) to each packet.

13. The module of aspect 12, wherein the identifying comprises using a special value for the SID.

14. The module of aspect 12, wherein the appended bit field comprises a dedicated CRC.

15. The module of aspect 9, wherein the at least one packet is not stored by the module for retransmission.

16. The module of aspect 9, wherein the at least one packet is passed by the module immediately to a high layer.

17. The module of aspect 9, wherein the module is implemented in one or more of a wireless transceiver, a wireless LAN station, a wired transceiver, a DSL modem, an ADSL modem, an xDSL modem, a VDSL modem, a multicarrier transceiver, a general purpose computer, a special purpose computer, a programmed microprocessor, a microcontroller and peripheral integrated circuit element(s), an ASIC, a digital signal processor, a hard-wired electronic or logic circuit and a programmable logic device.

18. The module of aspect 9, wherein the module is implemented in one or more of a PTM-TC, ATM-TC, PMD and PMS-TC.

19. A method comprising sharing memory between an interleaving and/or deinterleaving memory and a packet retransmission memory.

20. A method comprising allocating a first portion of shared memory for retransmission and a second portion of the shared memory for interleaving and/or deinterleaving.

21. The method of aspect 20, further comprising transmitting or receiving a message indicating how to allocate the shared memory.

22. The method of aspect 19 or 20, further comprising transmitting or receiving a message indicating how to share the memory.

23. A memory capable of being shared between an interleaving and/or deinterleaving buffer and a packet retransmission buffer.

24. A module capable of allocating a first portion of shared memory for retransmission and a second portion of the shared memory for interleaving and/or deinterleaving.

25. The module of aspect 24, wherein the module is capable of transmitting or receiving a message indicating how to allocate the shared memory.

26. The module of aspect 24, wherein the module is capable of transmitting or receiving a message indicating how to share the memory.

27. The module of aspect 24, wherein the module is one or more of a wireless transceiver, a wireless LAN station, a wired transceiver, a DSL modem, an ADSL modem, an xDSL modem, a VDSL modem, a multicarrier transceiver, a general purpose computer, a special purpose computer, a programmed microprocessor, a microcontroller and peripheral integrated circuit element(s), an ASIC, a digital signal processor, a hard-wired electronic or logic circuit and a programmable logic device.

28. A method of packet retransmission comprising:
- transmitting or receiving a plurality of packets;
- identifying at least one packet of the plurality of packets as a packet that should be retransmitted and at least one packet of the plurality of packets as a packet that should not be retransmitted.

29. The method of aspect 28, wherein the packet is any grouping of bytes.

30. The method of aspect 28, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

31. The method of aspect 28, wherein a bit field comprising a sequence identifier (SID) is appended to each packet.

32. The method of aspect 31, wherein the identifying step comprises using a special value for a sequence identifier (SID).

33. The method of aspect 31, wherein the appended bit field comprises a dedicated CRC.

34. The method of aspect 28, wherein at least one packet is stored for retransmission.

35. The method of aspect 28, wherein at least one packet is passed immediately to a high layer.

36. A packet handling method comprising:
- receiving a stream of packets;
- identifying a first number of packets in the stream of packets as low-latency packets;
- identifying a second number of packets in the stream of packets as low-error packets;
- forwarding the low-latency and low-error packets to a transceiver or a higher layer; and
- storing the low-error packets for error correction.

37. The method of aspect 36, further comprising appending the low-error packets with an identifier.

38. A method of allocating memory in a transceiver comprising:
- analyzing one or more communication parameters;
- identifying a memory allocation; and
- allocating memory based on the memory allocation to a retransmission function and one or more of interleaving, deinterleaving, RS coding and RS decoding.

39. A memory sharing method in a transceiver comprising:
- receiving a memory allocation;
- establishing a shared memory for one or more of interleaving, deinterleaving, RS coding, RS decoding and packet retransmission functions; and
- sharing the shared memory between a retransmission function and one or more of interleaving, deinterleaving, RS coding and RS decoding functions.

40. The method of aspect 39, further comprising determining a compatibility of the memory allocation.

41. The method of aspect 39, wherein the compatibility of the memory allocation is based on channel performance metrics.

42. Means for performing the functionality of any of the aforementioned aspects.

43. An information storage media comprising information that when executed performs the functionality of any of the aforementioned aspects.

44. Any one or more of the features as substantially described herein.

45. Means for packet retransmission comprising:
means for transmitting or receiving a plurality of packets;
means for identifying at least one packet of the plurality of packets as a packet that should not be retransmitted.

46. The means of aspect 45, wherein the packet is any grouping of bytes.

47. The means of aspect 45, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

48. The means of aspect 45, wherein a bit field comprising a sequence identifier (SID) is appended to each packet.

49. The means of aspect 48, wherein the means for identifying comprises using a special value for a sequence identifier (SID).

50. The means of aspect 48, wherein the appended bit field comprises a dedicated CRC.

51. The means of aspect 45, wherein the at least one packet is not stored for retransmission.

52. The means of aspect 45, wherein the at least one packet is passed immediately to a high layer.

53. Means for sharing memory between an interleaving and/or deinterleaving function and a packet retransmission function.

54. Means for allocating a first portion of shared memory for retransmission and a second portion of the shared memory for interleaving and/or deinterleaving.

55. The means of aspect 54, further comprising means for transmitting or receiving a message indicating how to allocate the shared memory.

56. The means of aspect 54, further comprising means for transmitting or receiving a message indicating how to share the memory.

57. Means for sharing a memory between an interleaving and/or deinterleaving function and a packet retransmission function.

58. Means for packet retransmission comprising:
means for transmitting or receiving a plurality of packets;
means for identifying at least one packet of the plurality of packets as a packet that should be retransmitted and at least one packet of the plurality of packets as a packet that should not be retransmitted.

59. The means of aspect 58, wherein the packet is any grouping of bytes.

60. The means of aspect 58, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

61. The means of aspect 58, wherein a bit field comprising a sequence identifier (SID) is appended to each packet.

62. The means of aspect 61, wherein the means for identifying comprises using a special value for the sequence identifier (SID).

63. The means of aspect 58, wherein the appended bit field comprises a dedicated CRC.

64. The means of aspect 58, wherein at least one packet is stored for retransmission.

65. The means of aspect 58, wherein at least one packet is passed immediately to a high layer.

66. A packet handling means comprising:
means for receiving a stream of packets;
means for identifying a first number of packets in the stream of packets as low-latency packets;
means for identifying a second number of packets in the stream of packets as low-error packets;
means for forwarding the low-latency and low-error packets to a transceiver or higher layer; and
means for storing the low-error packets for error correction.

67. The means of aspect 66, further comprising means for appending the low-error packets with an identifier.

68. Means for allocating memory in a transceiver comprising:
means for analyzing one or more communication parameters;
means for identifying a memory allocation; and
means for allocating memory based on the memory allocation to a retransmission function and one or more of an interleaving, deinterleaving, RS coding and RS decoding function.

69. Means for memory sharing in a transceiver comprising:
means for receiving a memory allocation;
means for establishing a shared memory for one or more of interleaving, deinterleaving, RS coding, RS decoding and packet retransmission function; and
means for sharing the shared memory between a retransmission function and one or more of interleaving, deinterleaving, RS coding and RS decoding functionality.

70. The means of aspect 69, further comprising means for determining a compatibility of the memory allocation.

71. The means of aspect 69, wherein the compatibility of the memory allocation is based on channel performance metrics.

72. A transceiver capable of performing packet retransmission comprising:
a transmission management module configurable to transmit or receive a plurality of packets; and
a QOS module configurable to identify at least one packet of the plurality of packets as a packet that should not be retransmitted.

73. The transceiver of aspect 72, wherein the packet is any grouping of bytes.

74. The transceiver of aspect 72, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

75. The transceiver of aspect 72, wherein a bit field comprising a sequence identifier (SID) is appended to each packet.

76. The transceiver of aspect 75, wherein the QOS module uses a special value for a sequence identifier (SID).

77. The transceiver of aspect 75, wherein the appended bit field comprises a dedicated CRC.

78. The transceiver of aspect 72, wherein the at least one packet is not stored for retransmission.

79. The transceiver of aspect 72, wherein the at least one packet is passed immediately to a high layer.

80. A memory capable of being shared between interleaving and/or deinterleaving and packet retransmission.

81. A memory management module capable of allocating a first portion of shared memory for retransmission and capable of allocating a second portion of the shared memory to one or more of interleaving and deinterleaving functionality.

82. The module of aspect 81, further comprising a module for transmitting or receiving a message indicating how to allocate the shared memory.

83. The module of aspect 81, further comprising a module for transmitting or receiving a message indicating how to share the memory.

84. A module capable of being shared between interleaving and/or deinterleaving and packet retransmission.

85. A transceiver capable of performing packet retransmission comprising:

a transmission management module configurable to transmit or receive a plurality of packets; and

QOS module configurable to identify at least one packet of the plurality of packets as a packet that should be retransmitted and at least one packet of the plurality of packets as a packet that should not be retransmitted.

86. The transceiver of aspect 85, wherein the packet is any grouping of bytes.

87. The transceiver of aspect 85, wherein the packet is one of an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data Frame, a PTM-TC codeword, an RS codeword and a DMT symbol.

88. The transceiver of aspect 85, wherein a bit field comprising a sequence identifier (SID) is appended to each packet.

89. The transceiver of aspect 88, wherein the identifying step comprises using a special value for a sequence identifier (SID).

90. The transceiver of aspect 88, wherein the appended bit field comprises a dedicated CRC.

91. The transceiver of aspect 85, wherein at least one packet is stored for retransmission.

92. The transceiver of aspect 85, wherein at least one packet is passed immediately to a high layer.

93. A transceiver capable of handling a stream of packets comprising:

a QOS module capable of identifying a first number of packets in the stream of packets as low-latency packets and a second number of packets in the stream of packets as low-error packets;

a transmission management module capable of forwarding the low-latency and low-error packets to another transceiver; and

a buffer module capable of storing the low-error packets for error correction.

94. The transceiver of aspect 93, further comprising a packet QOS assignment module capable of appending the low-error packets with an identifier.

95. A transceiver capable of having an allocatable memory comprising:

a controller capable of analyzing one or more communication parameters; and

a memory management module capable of identifying a memory allocation and allocating a shared memory based on the memory allocation to a retransmission function and one or more of interleaving, deinterleaving, RS coding and RS decoding functions.

96. A transceiver capable of sharing memory comprising:

a controller capable of receiving a memory allocation; and

a memory management module capable of establishing a shared memory for a retransmission function and one or more of interleaving, deinterleaving, RS coding and RS decoding functions.

97. The transceiver aspect 96, wherein the memory management module further determines a compatibility of the memory allocation.

98. The transceiver of aspect 96, wherein the memory allocation is based on one or more communication channel performance metrics.

99. In a communication environment where packets are being transmitted, a method for allocating a first portion of shared memory for retransmission of packets and a second portion of the shared memory for interleaving and/or deinterleaving.

100. The method of aspect 99, wherein all errored packets are retransmitted.

101. The method of aspects **19**, **20** and **99**, wherein a retransmission function identifies packets that should not be retransmitted.

102. The method of aspect 99, wherein all packets are being transmitted without an assigned a QOS level.

103. A packet communication method comprising:

in a first mode of operation:

transmitting or receiving a plurality of packets;

identifying at least one packet of the plurality of packets as a packet that should not be retransmitted;

in a second mode of operation:

transmitting or receiving a plurality of packets;

allocating a first portion of shared memory for retransmission of packets and a second portion of the shared memory for one or more of interleaving, deinterleaving, coding, decoding and error correction; and

in a third mode of operation:

transmitting or receiving a plurality of packets;

identifying at least one packet of the plurality of packets as a retransmittable-type packet;

identifying at least one packet of the plurality of packets as a non-retransmittable-type packet;

allocating a first portion of shared memory for retransmission of the retransmittable-type packets and a second portion of the shared memory for one or more of interleaving, deinterleaving, coding, decoding and error correction.

104. The method of aspect 103, wherein the retransmittable-type packet is a low-latency packet.

105. The method of aspect 103, wherein the retransmittable-type packet is a low-error packet.

These and other features and advantages of this invention are described in, or are apparent from, the following detailed description of the exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The exemplary embodiments of the invention will be described in detail, with reference to the following figures wherein:

FIG. **1** illustrates an exemplary communication system according this invention.

FIG. **2** is a flowchart outlining an exemplary method for packet retransmission according this invention.

FIG. **3** is a flowchart outlining an exemplary method for retransmitted packet reception according this invention.

FIG. **4** is a flowchart outlining an exemplary method for memory allocation according to this invention.

FIG. **5** is a flowchart outlining an exemplary method for memory sharing according this invention.

DETAILED DESCRIPTION

The exemplary embodiments of this invention will be described in relation to packet retransmission and/or memory sharing in an xDSL environment. However, it should be appreciated, that in general, the systems and methods of this invention will work equally well for any type of communication system in any environment.

The exemplary systems and methods of this invention will also be described in relation to multicarrier modems, such as xDSL modems and VDSL modems, and associated communication hardware, software and communication channels. However, to avoid unnecessarily obscuring the present invention, the following description omits well-known structures and devices that may be shown in block diagram form or otherwise summarized.

For purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the present invention. It should be appreciated however that the present invention may be practiced in a variety of ways beyond the specific details set forth herein.

Furthermore, while the exemplary embodiments illustrated herein show the various components of the system collocated, it is to be appreciated that the various components of the system can be located at distant portions of a distributed network, such as a communications network and/or the Internet, or within a dedicated secure, unsecured and/or encrypted system. Thus, it should be appreciated that the components of the system can be combined into one or more devices, such as a modem, or collocated on a particular node of a distributed network, such as a telecommunications network. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the system can be arranged at any location within a distributed network without affecting the operation of the system. For example, the various components can be located in a Central Office modem (CO, ATU-C, VTU-O), a Customer Premises modem (CPE, ATU-R, VTU-R), an xDSL management device, or some combination thereof. Similarly, one or more functional portions of the system could be distributed between a modem and an associated computing device.

Furthermore, it should be appreciated that the various links, including communications channel **10**, connecting the elements (not shown) can be wired or wireless links, or any combination thereof, or any other known or later developed element(s) that is capable of supplying and/or communicating data to and from the connected elements. The term module as used herein can refer to any known or later developed hardware, software, firmware, or combination thereof that is capable of performing the functionality associated with that element. The terms determine, calculate and compute, and variations thereof, as used herein are used interchangeably and include any type of methodology, process, mathematical operation or technique. Transmitting modem and Transmitting transceiver as well as Receiving modem and Receiving transceiver are used interchangeably herein.

Moreover, while some of the exemplary embodiments described herein are directed toward a transmitter portion of a transceiver performing interleaving and/or coding on transmitted information, it should be appreciated that a corresponding deinterleaving and/or decoding is performed by a receiving portion of a transceiver. Thus, while perhaps not specifically illustrated in every example, this disclosure is intended to include this corresponding functionality in both the same transceiver and/or another transceiver.

Communication system **100** comprises a portion of a transceiver **200** and a portion of a transceiver **300**. The transceiver **200**, in addition to well known componentry, comprises an errored packet module **210**, a transmission management module **220**, a QOS ID module **225**, a QOS module **230**, a packet QOS assignment module **240**, a retransmission buffer/interleaving/deinterleaving/RS coding/RS Decoding memory **250**, a counter module **260**, a memory management module **270** and a controller/memory **280**.

Connected via communication channel **10** to transceiver **200** is transceiver **300**. The transceiver **300**, in addition to well known componentry, comprises an errored packet module **310**, a transmission management module **320**, a QOS ID module **325**, a QOS module **330**, a packet QOS assignment module **340**, a retransmission buffer/interleaving/deinterleaving/RS coding/RS Decoding memory **350**, a counter module **360**, a memory management module **370** and a controller/memory **380**.

As discussed above, the systems, methods and protocols discussed herein will be described in relation to xDSL systems, such as those specified in ADSL2 ITU-T G.992.3, ADSL2++ITU G.992.5, and VDSL2 ITU G.993.2, which are incorporated herein by reference in their entirety.

In operation, a first aspect of the invention relates to retransmission of one or more packets, the retransmission identifier being implemented at any transmission layer where packet boundaries are defined. For example, it can be implemented in the Packet Transmission Mode TC (PTM-TC) of xDSL systems. For reference, “Annex A” which is of record in the identified provisional filing and incorporated by reference herein contains the PTM-TC of ADSL2 and VDSL2 systems as specified in the ITU-T G.992.3 ADSL2 standard.

As discussed herein, the invention will generally be described in relation to the retransmission mechanism being incorporated as part of the PTM-TC however, it should be appreciated that it can also be implemented inside other layer(s) of a communication device, such as an xDSL transceiver, such as within the PMD or PMS-TC.

The retransmission techniques disclosed herein can also be performed at a layer above the PTM-TC, for example, in a new layer between the PTM-TC and the next higher layer, or at any layer above the physical layer, e.g., layers 2, 3, 4, 5, etc.

Additionally, while “packet” is used herein, the term “packet” includes any basic data unit, i.e., a grouping of bytes. For example, a packet could be an IP packet, an Ethernet packet, an ATM cell, a PTM packet, an ADSL Mux-Data frame, a PTM-TC codeword, an RS Codeword, a DMT symbol, or, in general, any grouping of data bytes or information. A packet could also be a combination of one or more of the above. For example, a packet could be constructed by concatenating any number of ATM cells to create a larger grouping of bits. For example, five 53-byte ATM cells could be combined into a 265 byte packet or four 65 PTM-TC codewords could be combined into a 260 byte packet. A packet could also be based on dividing any of the above groupings of bytes. For example, larger IP or Ethernet packets could be divided into smaller groups of bytes to be used as a “packet” with the retransmission functionality described herein. For example, a 1500 byte IP packet could be divided into three 500 byte packets and used by the retransmission protocol. If the retransmission function is implemented as part of the PTM-TC, packets are received from a higher-layer in the xDSL transmitter PTM-TC and sent via the xDSL transmitter PMS-TC and PMD over the communication channel to the xDSL receiver. The xDSL receiver PMD and PMS-TC process the received signal and pass the results to the PTM-TC, which processes the information and passes the received packet up to a higher layer(s).

Packets received from the higher layer at the xDSL transmitter PTM-TC can be designated to have a QOS level. The QOS level of a packet can indicate the importance of certain service metrics (or characteristics) of this (or more) packet(s). Two exemplary QOS metrics are delay (or latency) and PER. Although, as discussed above, these two characteristics are the focus of the invention, any number of different QOS metrics could also be used.

As an example, in the case where the 2 QOS metrics are latency and PER, a first set of packets carrying certain information may have a requirement for very low PER but may be able to tolerate higher delay. Other packets containing information such as voice or data traffic may have very low delay requirements but can tolerate a higher PER. According to an exemplary embodiment of this invention, the first set of packets would be designated as “low-PER” QOS packets whereas voice or data packets would be designated at “low-latency”

QOS packets. The QOS level (or metric) of a packet could be designated in a number of ways. For example:

i) Certain bit fields in the header of data portions of each packet could contain certain values that specify the QOS requirements a packet. For example, the packet header could contain bit fields that indicate if the packet has a "low-PER" QOS requirement or a "low-latency" QOS requirement. These fields could be read by the transmitting modem and/or receiving modem to determine the QOS level of each packet.

ii) When sending packets from higher layer to the PTM-TC, the higher layer could indicate on a packet by packet basis the QOS requirements of each packet. For example, there could be a separate signal on the interface that indicates if a packet being transferred has a "low-PER" QOS requirement or a "low-latency" QOS requirement.

iii) When sending packets from higher layer to the PTM-TC, there could be a separate interface (or channel) for packets with different QOS requirements. For example, one channel could be used to transfer packets that have a "low-PER" QOS requirement and a second channel could used to transfer packets that have a "low-latency" QOS requirement. This general concept could also be scaled to accommodate a plurality of different QOS requirements and a plurality of channels.

iv) As in the case of Pre-Emption in the PTM-TC (see Annex A), two logically separated γ-interfaces could be used for the transport of a low-PER and low-latency packet flow through a single bearer channel. This general idea could then be scaled to support any number of packet types.

Other mechanisms can also be used to designate the QOS level of a packet-provided the transmitter and/or receiver retransmission protocol is capable of knowing the QOS level for one or more packets.

Once the QOS level is known by the PTM-TCs, an efficient packet retransmission can be designed. The exemplary packet retransmission methods and protocols can be designed to include any one or more of the following system level characteristics:

- All packets are received from the higher layer and passed to the higher layers in the correct order.
- "Low-latency" QOS packets will not incur any extra delay due to retransmission.
- Only packets with "low-PER" QOS should be retransmitted, and therefore only low-PER packets will incur the extra delay due to the retransmission mechanism.
- Flow control can be minimized such that the transmitter can generally accept all packets from the higher layer at the required data rate without holding-off (or "blocking") packets from the higher layer during the retransmission process.
- Packet delay-variation/jitter can be minimal
- A "DRR-like" functionality in a single bearer without requiring latency/interleaver OLR.

The transceiver **200**, in cooperation with the QOS module **230**, receives packets from a higher-layer. In cooperation with the packet QOS assignment module **240**, a packet Sequence ID (SID) is appended to the received packets. The packets, in cooperation with the transmission management module **220**, can then be transmitted in the order in which they were received.

The QOS Module **230**, if not already performed by a high layer, also identifies packets based on the QOS requirement of the packet(s). Then, in cooperation with the packet QOS assignment module **240**, a QOS identifier is associated with the packet as discussed hereinafter.

If, for example, the packet is identified as a low-PER packet, and assigned such an identifier by the QOS module **230**, when the transmission management module **220** receives the packet, the packet is identified by the QOS ID module **225** as being a low-PER packet and the packet is forwarded for storage in the retransmission buffer **250**. Alternatively, if the packet has been labeled as a low-latency packet, and identified as such by the by the QOS ID module **225**, the packet can be transmitted to the receiving modem in cooperation with the transmission management module **220**.

The low-PER packets can be stored for a sufficient amount of time to wait for a retransmission message from the receiver PTM-TC. During this time, the transmitting modem can continue to receive packets from one or more higher layers, label these packets, if needed, and store these packets, if they are identified as low-PER packets, in the same way. The resulting minimum storage requirements for the transmitter PTM-TC are estimated below.

For successful retransmission, the receiving modem should be able to inform the transmitting modem which packet, or packets, need to be retransmitted. One exemplary way of performing this is by transmitting packets with an appended bit field that contains a counter indicating the place of each packet in a stream of packets. This counter value is also known as a Sequence ID (SID). For example, a bit field containing a 16-bit counter could be appended to each packet and the counter module **260** would be incremented by one after each packet was transmitted. In cooperation with the packet assignment module **240**, a packet counter field could be appended to the packet in a number of places, for example, at the beginning or end of the packet, or at the beginning or end of the packet header.

Packets received from a higher-layer may already have information in a header or data field of the packet that contains the packet count, or sequence, information. In addition, the packet counter field may be appended with an additional CRC field that contains a cyclic redundancy check that is computed on the packet counter field bits only. This CRC can be used by the receiver to determine if the packet counter field is received correctly, i.e., without bit errors. This CRC can be in addition to the standard CRC inserted by the standard PTM-TC (the standard packet PTM-TC CRC is a CRC that covers all bits in a packet). The standard packet CRC may also cover the new packet counter field in its CRC as well. This helps if the receiving modem uses the presence or absence of the packet counter field in a packet to detect if the packet has a low-PER or low-latency requirement (discussed below).

Alternatively, or in addition, the packet counter field (with or without a dedicated CRC) can be appended only to the packets with a specific QOS requirement, whereas all other packets can be transmitted without modification. For example, all video packets with low-PER QOS could contain the appended packet counter field whereas all the voice/data low-latency packets could be transmitted unchanged. One exemplary benefit of this is that the overhead (rate loss) due to adding the packet counter field is incurred only when transmitting low-PER packets.

Alternatively, or in addition, all low-PER and low-latency packets can be transmitted with the low packet counter field (with or without a dedicated CRC). In this case, the packet counter field of the low-latency packets may contain a special value indicating that a packet is not a low-PER packet. Also, the packet counter field of the low-latency packet may not even contain a count value, since the low-latency packets are not intended to be retransmitted. In this case, the packet counter field could contain a counter value only for low-PER packets and the counter value would only be incremented when a low-PER packet was transmitted. As an example, if the packet counter field is 16 bits, the special value of all zeros

could be used to indicate that a packet is a low-latency packet. In this case, low-PER packets could contain counter values from one up to $2^{16}-1$, but not including all zeros, since this special zero value can be used to indicate a low-latency packet.

The receiving modem, e.g., receiver PTM-TC, which in this case is illustrated as the transceiver **300** and includes comparable functionality to that described in relation to transceiver **200**, receives packets from the transmitting modem via the PMS-TC. If the received packet is identified as a low-latency packet by the QOS ID module **325**, the packet is passed to a higher-layer. If a received packet is identified by the QOS ID module **325** as a low-PER packet, the packet is forwarded, with the cooperation of the transmission management module **320**, to the retransmission buffer **350** for a minimum amount of time before passing to a higher-layer.

The storage time in the retransmission buffer **350** helps ensure that the retransmission protocol provides a constant delay, e.g., no delay variation seen by the upper layers. This way, if a packet needs to be retransmitted, the receiving modem can continue to provide packets to the higher-layers at a constant rate while waiting for the retransmitted packet(s) to arrive from the transmitting modem. The resulting minimum memory (or storage) requirements for the receiving PTM-TC are estimated below.

Alternatively, low-PER packets without errors may not be stored for a minimum amount of time before passing to a higher-layer. The error-free low-PER packets can be passed to the higher-layer immediately just like the low-latency packets. However, when a low-PER packet is in error, it is stored along with all of the following low-PER packets before passing to a higher-layer in order to wait for the retransmitted packet(s) to arrive. This will cause a delay variation on the low-PER packets whenever a retransmission occurs. However, this delay variation would not apply to the low-latency packets.

The QOS ID module **325** can detect that a packet is either low-PER or low-latency using several different methods. For example, if all low-PER and low-latency packets contain the appended packet counter field, then the receiving modem, in cooperation with the counter module **360**, detects a low-latency packet when a packet counter field contains the designated special value, which was inserted by the transmitting modem, indicating the packet is a low-latency packet.

Alternatively, or in addition, the receiver could detect a low-PER packet when the packet counter field contains a valid packet counter value. Additionally, if a dedicated CRC is appended to the packet counter field, the CRC could be used to detect if the packet counter field bits are in error.

If the packet counter field, including the CRC, is only appended to low-PER packets, the absence or presence of this field in a packet can be used by the receiving modem, and in particular the QOS ID module, to detect a low-delay packet. For example, the receiving modem can examine the position in the packet where the packet counter field would be, if it was a low-PER packet, and if the packet counter field CRC fails while the standard whole packet CRC is correct, the receiving modem could determine that the packet is a low-delay packet, since it does not contain the packet counter field. Likewise, for example, the receiving modem can examine the position in the packet were the packet counter field would be, if it was a low-PER packet, and if the packet counter field CRC is correct, the receiving modem would determine that the packet is a low-PER packet, regardless of the status of the standard whole packet CRC.

The receiving modem, in cooperation with the retransmission buffer **350**, and the errored packet module **310**, can be used to detect missing or errored packets in a number of exemplary ways. For example, the errored packet module **310** can detect bit errors in the packet using the standard/whole packet PTM-TC CRC. Alternatively, or in addition, the errored packet module **310** can detect bit errors in the packet counter field if the transmitting modem appended a dedicated CRC to the packet counter field. This CRC is valuable because it can be used by the errored packet module in the receiving modem to determine if a packet has the correct packet number, even if the standard whole packet CRC happens to be in error.

Alternatively, or in addition, the errored packet module **310**, can detect an errored or missing packet by receiving a packet with a correct CRC, either in the standard or packet counter field, which contains a packet counter number that is not the expected packet counter number. For example, if the errored packet module **310**, in cooperation with the counter module **360**, detects the receipt of a packet with a counter number equal to 5, wherein the errored packet module **310** is expecting to receive a packet with a counter equal to 3, the errored packet module **310** can determine that two packets, namely packets numbered 3 and 4, were lost due to errors.

Once a packet(s) is found to be in error, there are several exemplary ways in which a receiving modem can communicate information to the transmitting modem indicating that a retransmission of one or more packets is required. For example, the receiving modem, in cooperation with the errored packet module **310**, can send an acknowledgment (ACK) message to the transmitting modem for every correctly received message or every predetermined number of packets. As long as the transmitting modem, and in particular the errored packet module **210**, receives messages acknowledging receipt of packets in sequential order, there is no need for retransmission of information to the receiving modem. However, if the transmitting modem, and in particular the errored packet module **210**, receives a message from the receiving modem, and in particular the errored packet module **310**, indicating that a packet was correctly received with a counter value that is out of order, a retransmission by the transmitting modem is required. In the above example, where the receiving modem received a packet with a counter value equal to 5, without receiving packets numbered 3 and 4, the transmitting modem could receive an ACK for the packet with counter value of 2 and then an ACK for the packet with a counter value of 5. The transmitting modem would then determine that it was necessary to retransmit packets with counter values of 3 and 4 since they were not received.

Alternatively, or in addition, a timeout value could be specified for the transmitting modem. This timeout value could correspond to the amount of time that the transmitting modem should wait for an ACK for particular packet before retransmitting the packet. The timeout value could be set to be at least as long as the round-trip delay required for the transmitting modem to send a packet to the receiving modem and for the receiving modem to send an ACK back to the transmitting modem. If an ACK is not received by the timeout value, the transmitting modem could retransmit the packet.

Alternatively, or in addition, a negative acknowledgment (NAK) could be sent to the transmitting modem when a packet is detected as errored or missing. In the above example, when the receiving modem received the packet with a counter value of 5, while expecting a counter value of 3, the receiving modem could send a NAK message to the transmitting modem indicating that packets with counter values of 3 and 4 were not correctly received and needed to be retransmitted.

Alternatively, or in addition, if a packet was received with a correct packet counter CRC and a valid packet counter value α and an incorrect standard whole packet CRC, the receiving modem could send a NAK message to the transmitting modem indicating that a packet with a value of α was incorrectly received and needed to be retransmitted.

Assuming that errored packets are infrequent, any methodology that sends an ACK for each correctly received packet can require a larger amount of data rate in the message channel that communicates this information back to the transmitting modem. In this case, sending only NAKs has the benefit that it requires sending a message only when an errored or missing packet is detected. Depending on the data rate capabilities of the message channel, and the PER, a retransmission system may use only ACKs, only NAKs, or both ACKs and NAKs at the same time.

The ACK and NAK messages sent back to the transmitting modem can be transmitted over the same physical channel i.e., phone line, in the opposite direction as the received packets. Since the channel has a limited data rate and is not necessarily error-free, it is important to make sure that these messages are as robust as possible and consume the least amount of data rate. Additionally, since the transmit and receive retransmission memory requirements depend on the round-trip latency of the connection, is important to minimize latency requirements for the message channel. There are several ways these requirements can be addressed.

The messages can be sent over a separate "low-latency" or "fast" path between the xDSL transceivers. This fast path could include little or even no delay due to interleaving and can be specified to have a latency that is less than 2 ms.

Alternatively, or in addition, the messages can be sent with increasing robustness by repeating transmission of each message a number of times. For example, the message could be repeated x times in order to make sure that even if x−1 messages were corrupted by the channel, at least one message would be received correctly.

Alternatively, or in addition, the messages can be sent such that each message is repeated a number of times and each repeated message is sent in a different DMT symbol. For example, the message can be repeated x times and each message sent in one of x DMT symbols. This way, even if x−1 DMT symbols were corrupted by the channel, at least one message would be received correctly.

Alternatively, or in addition, the messages can be sent such that each message is repeated a number of times and each repeated message is sent in different DMT symbols. For example, the message could be repeated x times and each message sent in one of x DMT symbols. This way, even if x−1 DMT symbols were corrupted by the channel, at least one message would be received correctly.

Alternatively, or in addition, the messages can be sent such that each message is repeated a number of times and each repeated message is sent a plurality of times in each DMT symbol. For example, the message could be repeated x times and each repeated message sent y times in one of x DMT symbols. This way, even if x−1 DMT symbols were corrupted by the channel and/or large portions of a DMT symbol were corrupted by a channel, the least one message would be received correctly.

Alternatively, or in addition, the messages can include multiple packet count values in order to reduce the data rate requirements. For example, if packets with counter values of 3-9 are correctly (or incorrectly) received an ACK (or NAK) message would be sent to indicate these packet values. For example, the message could contain the values 3 and **9** and the receiver of the message would automatically know that all intermediate values (4, 5, 6, 7, 8) are also been indicated in the message.

Alternatively, or in addition, the DMT sub-carriers that modulate these messages could operate with a much higher SNR margin e.g., 15 dB, as compared to the normal 6 dB margin of xDSL systems. This way, the messages would have a higher immunity to channel noise.

Alternatively, or in addition, a receiving modem may need to send an additional ACK or NAK message after already in the process of sending a repeated message. For example, a receiving modem may detect that packets with values 3 to 9 have been correctly received and send an ACK message back to the transmitting modem indicating this information. This message can be repeated x times with each repeated message being transmitted (at least once) on different DMT symbols. While sending the second repeated message on the second DMT symbol, the receiver could detect that packets with values 10 to 17 have now also been correctly received. In this case, the receiving modem could just append this information to the previous message or, alternatively, send a new separate message that is repeated as well x times with each repeated message being transmitted (at least once) on a different DMT symbol.

Alternatively, or in addition, when repeating a message x times on x DMT symbols, each repeated message can be modulated on a different set of DMT sub-carriers on each DMT symbol. This way, if one or more sub-carriers have a low SNR, the message will still be correctly received.

For low-PER packets, the delay due to this retransmission protocol is equal to the delay that results from storing these packets at the receiving modem (RX PTM-TC) to pass in the packets to a higher layer. Low-latency packets do not incur extra delay.

The transmitting modem must store a packet for retransmission for a time equal to the round trip delay from when the packet is sent to when the retransmission message is received. During this time the transmitting modem continues to receive packets from the higher layer and continues to store these packets in the same way. Therefore the storage requirements in octets can be computed as:

$$\text{Minimum } TX \text{ memory(octets)} = \text{roundtripdelay} * \text{datarate},$$

where the roundtripdelay is the time equal to the round trip delay from when the packet is sent to when the retransmission message is received, and the datarate is the data rate of the connection that is transferring the packets.

For ITU-T G.993.2 VDSL2, which is incorporated herein by reference, this can be computed using the VDSL2 profile parameters as:

$$\text{Minimum } TX \text{ memory(octets)} = (DS+US \text{ Interleaving Delay in octets}) + (US+DS \text{ alpha/beta delay without interleaving}) * (\text{Bidirectional Net data rate}) = \text{MAXDLEYOCTET} + (4 \text{ ms}) * MBDC,$$

where MAXDELAYOCTET and MBDC are as specified in the VDSL2 profiles.

For the receiver, the minimum receiver storage requirements can be determined in a similar manner. More specifically, the RX PTM-TC must store a packet before passing it to the higher layer for a time equal to the round trip delay from when a retransmission message is transmitted to when the retransmitted packet is received. This is equal to storage requirements in octets (same as transmitter):

$$\text{Minimum } RX \text{ memory(octets)} = \text{roundtripdelay} * \text{datarate},$$

where the roundtripdelay is the time equal to the round trip from when a retransmission message is transmitted to when the retransmitted packet is received and the datarate is the data rate of the connection that is transferring the packets.

For ITU-T G.993.2 VDSL2 this can be computed using the VDSL2 profile parameters as:

Minimum *RX* memory(octets)=(*DS*+*US* Interleaving Delay in octets)+(*US*+*DS* alpha/beta delay without interleaving)*(Bidirectional Net data rate)= MAXDLEYOCTET+(4ms)**MBDC*,

where MAXDELAYOCTET and MBDC are as specified in the ITU-T G.993.2 VDSL2 profiles.

TABLE 1

Minimum TX or RX memory requirements for VDSL2

VDSL2 PROFILE	8a, 8b, 8c, 8d	12a, 12b	17a	30a
TX or RX memory requirements (octets) = MAXDLEYOCTET + .002MBDC	90,536	99,536	123,304	231,072

The estimates in Table 1 assume that all the entire MAXDELAYOCTET and MBDC are used for the transfer of the packet stream, i.e., the reverse channel has a very low data rate and no interleaving.

Some xDSL standards specify minimum storage, i.e., memory, requirements for interleaving of RS codewords. Interleaving with RS coding is an effective way of correcting channel errors due to, for example, impulse noise. For example, VDSL2 requires support of an aggregate bidirectional interleaver and de-interleaver memory of 65 Kbytes for the 8a VDSL2 profile. This corresponds to storage requirement of approximately 32 Kbytes in a single transceiver.

Sharing of Memory Between the Retransmission Function and One or More of the Interleaving/Deinterleaving/RS Coding/RS Decoding Functions

From Table 1, it is apparent that the memory requirements to support the retransmission protocol may be more than double the storage requirements of a single transceiver. Additionally, the retransmission protocol provides a different method for correcting channel errors due to, for example, impulse noise.

Moreover, interleaving and RS coding methods and retransmission protocols provide different advantages with respect to error correction capabilities, latency, buffering requirements, and the like. For example, under certain configuration and noise conditions the interleaving/RS coding provides error correction/coding gain with less delay and overhead than the retransmission protocol (for packets that can be retransmitted). While under other conditions the retransmission protocol will provide better error correction with less delay and overhead than the interleaving/RS coding.

In some cases, a first portion of the memory can be used for one function and a second portion of the memory for some other function. For example, if the configuration and noise conditions are such that the interleaving/RS coding would not provide good error correction/coding gain, then all the available memory could be used for the retransmission function and none allocated to the interleaving/deinterleaving/RS coding/RS decoding functionality, e.g., the interleaving/deinterleaving could be disabled.

Likewise, if the configuration and noise conditions are such that the retransmission protocol would not provide good error correction/coding gain, then all the available memory could be used for the interleaving/deinterleaving/RS coding/RS decoding functionality and no memory would be used for the retransmission function, e.g., the retransmission function would be disabled.

Alternatively, or addition, both methods could be used because both have their advantages, with the system, e.g., the memory management module **370**, being able to dynamically allocate a first portion of the memory **250**/**350** to the interleaving/deinterleaving/RS coding/RS decoding functionality and a second portion of the memory to the retransmission functionality. For example, 40% of the memory could be allocated to the interleaving/deinterleaving/RS coding/RS decoding functionality with the remaining 60% allocated to the retransmission of functionality. However, it should be appreciated, that in general, the memory can be divided, i.e., shared, in any manner.

The sharing of memory between the retransmission function and the interleaving/deinterleaving/RS coding/RS decoding functions is not restricted to retransmission protocols described in other embodiments that utilize QOS metrics to determine which packets should be retransmitted. In other words, the sharing of memory between the retransmission function and the interleaving/deinterleaving/RS coding/RS decoding functions can be utilized for retransmission systems where all errored packets are retransmitted, i.e., there is no QOS identifier in the retransmission protocol. For example, the FEC/interleaving could be used to meet the INPmin requirement specifically targeting the impulse noise that occurs frequently (e.g., on the order of minutes or seconds) but is short in duration and can therefore be corrected by the FEC/interleaving. For example, the retransmission protocol can be used to correct infrequent errors (on the order of hours) that are long in duration and would not be correctable by the FEC/interleaving. As another example, the FEC/interleaving function may be used in combination with the retransmission function because it is well known that FEC with minimal interleaving provides a 1 dB to 3 dB coding gain when used with a trellis code (as is often the case in xDSL systems). This means that even when the majority of the shared memory is allocated to a retransmission function to address channel noise (such as impulse noise), a smaller amount of memory may be allocated to the FEC/interleaving function for the coding gain advantage.

Associated with the ability to allocate or partition memory between one or more of the interleaving/deinterleaving/RS coding/RS decoding functionality and retransmission functionality, is the ability to exchange information between transceivers on how to establish this allocation. For example, the transmitting modem may send a message to the receiving modem indicating how much of the available memory is to be allocated to one or more of the interleaving/deinterleaving/RS coding/RS decoding functionality and how much memory is to be allocated to the retransmission functionality. For example, if the receiving modem contains 100 kBytes of available memory, the transmitting modem could send a message to the receiving modem indicating that 25 kBytes should be allocated to RS coding functionality and 75 kBytes should be allocated to the retransmission functionality. Since the receiving modem generally determines the interleaving/RS coding parameters that are used, the receiving modem could use this information to select parameters, e.g., interleaver depth and codeword size, that would result in an interleaving memory requirement that is no more than the amount indicated in the message.

Alternatively, or addition, the receiving modem can send a message to the transmitting modem indicating how much of the available memory is to be allocated to one or more of the

interleaving/deinterleaving/RS coding/RS decoding functionality, and how much memory should be allocated to the retransmission functionality.

Sharing of Memory Between a Retransmission Function with Identification of Low-PER and/or Low-Latency Packets and One or More of Interleaving/Deinterleaving/RS Coding/RS Decoding Functions.

A way of reducing the total memory requirement of a transceiver that supports the retransmission functionality with the identification of the low-PER and/or the low-latency packets is to define a limit, such as a maximum value, for the data rate of the low-PER packet stream, i.e., the packets requiring retransmission to meet a specific PER requirement. For example, if the total date rate is 50 Mbps, and the roundtrip delay is 10 ms, the minimum TX or RX memory requirement is 50,000,000*.01/8=62500 bytes if the retransmission function must support the case where all the transmitted packet (all 50 Mbps) are low-PER packets. If however, only a portion of the 50 Mbps data rate is allocated to the low-PER packet stream (e.g. 30 Mbps), whereas the remainder of the data rate is allocated to the low-latency packet stream (e.g. 20 Mbps), the minimum TX or RX memory requirement would be 30,000,000*.01/8=37500 bytes (assuming a roundtrip delay of 10 ms). In this case, the transmitting modem (or receiving modem) may send a message to the receiving modem (or transmitting modem) that indicates the maximum data rate of the packet traffic that will be used in the retransmission function. Using the example above, the transmitting modem (or receiving modem) would send a message indicating that the low-PER traffic will not exceed 30 Mbps, in which case the receiving modem (or transmitting modem) will allocate memory to the retransmission functionality and the interleaving/RS coding (or deinterleaving/RS decoding) functionality accordingly.

One exemplary advantage of indicating the low-PER and low-latency packets as part of the retransmission protocol is that it provides a DDR-like functionality without the overhead of dynamically re-allocating latency paths. For example, when a video application is turned off (less low-PER packets on the connection), the data application data rate can be increased (more low-latency packets on the connection) without any changes in the transmission parameters.

The retransmission protocol can also be used with or without underlying FEC/interleaving (or deinterleaving). An exemplary approach is to use the FEC/interleaving to meet the INPmin requirement specifically targeting the impulse noise that occurs frequently, e.g., on the order of minutes or seconds. The retransmission protocol can be used to correct infrequent errors (on the order of hours) that will only typically be a problem for very-low PER applications, such as video.

When a retransmission protocol is combined with underlying FEC/interleaving (or deinterleaving), the retransmission protocol latency will grow in proportion to the additional FEC/interleaving delay. This is due to the fact that the required receiver buffering corresponds approximately to the round-trip delay time of packet transmission and message acknowledgment.

As an example of utilizing the retransmission protocol that identifies one or more of low-PER and low-latency packets with underlying FEC/Interleaving (or deinterleaving), the FEC/interleaving is used to achieve the INPmin requirements within the latency constraint and the retransmission function is used to provide another layer of error correction. The low-PER packets are passed through both the retransmission function and the FEC/interleaver and, as a result, a very low PER is achieved. The low-latency packets are passed through the FEC/Interleaver but not passed through the retransmission function. Since low-latency packets are passed through the FEC/interleaver, they will meet the INPmin and MaxDelay requirements without incurring the extra delay from the retransmission protocol.

Example Configuration Parameters:

DS Data rate=25 Mbps, INPmin=2, MaxDelayDS=8 ms

Example FEC/Interleaving Parameters:

NFEC=128, R=16 which results in an interleaver memory of approximately 14 Kbytes for INP=2 with 8 ms of delay.

Retransmission Protocol:

If we assume the US latency is 2 ms, the retransmission protocol will add a minimum of 8+2=10 ms of latency. This means that the total DS latency (FEC/interleaving+Retransmission) will be approximately 8+10=18 ms.

Memory Requirements:

The memory requirements for the retransmission protocol can be calculated as: (10 ms)×(25 Mbps)/8=31 Kbytes. Therefore the transmitter and receiver will both need a total memory of (31+14)=45 Kbytes for the retransmission protocol and FEC/Interleaving function.

Low-Per Packets:

Latency=18 ms. The PER is very low because INPmin=2 (from FEC/interleaving) is combined with the error correction of the retransmission function.

Low-Latency Packets:

Latency=8 ms. INP=2 from FEC/interleaving. No additional delay due to retransmission function.

Although this invention describes the retransmission being done as part of the PTM-TC, it could also be done inside other layer(s) of the xDSL transceiver, such as the PMD or the PMS-TC. Alternatively, it could performed at a layer(s) above the PTM-TC, for example, in a new layer between the PTM-TC and the next higher layer, or in general any layer above the physical layer, e.g., layer 1, 2, 3, 4 or 5.

In this invention, the term "transmitter" generally refers to the transceiver that transmits the packets. Likewise the term "receiver" generally refers to the transceiver that receives the packets. Therefore the "transmitter" also receives the ACK/NAK messages and the "receiver" also transmits the ACK/NAK messages.

FIG. **2** outlines an exemplary method of operation of a transmitting modem utilizing the retransmission protocol. In particular, control begins in step S**100** and continues to step S**110**. In step S**110**, a packet is received from a higher layer. Then, in step S**120**, a decision is made as to whether the received packet is a retransmitted type packet. If the packet is not a retransmitted type packet, such as a low-latency packet, control jumps to step S**125** where the packet is optionally updated (as discussed above) with control continuing to step S**130** where the packet is forwarded to the receiver. Control then continues to step S**140** where the control sequence ends.

If the packet is a retransmitted type packet, such as a low-PER packet, control continues to step S**150**. In step S**150**, the packet can be updated with information such as a sequence identifier or other information that allows a receiver to be able to determine which packet (or packets) need to be retransmitted. Next, in step S**160**, the updated packet is stored in the retransmission buffer. Then, in step S**170**, the packet is forwarded to the receiver. Control then continues to step S**180**.

In step S**180**, a determination is made whether the packet needs to be retransmitted. If the packet needs to be retransmitted, control jumps back to step S**170**. Otherwise, control continues to step S**190**.

In step S**190**, the packet is deleted from the retransmission buffer. Control then continues to step S**140** where the control sequence ends.

FIG. **3** outlines an exemplary method of operation of a receiving modem utilizing the retransmission protocol. In particular, control begins in step S**200** and continues to step S**210**. In step S**210**, a packet is received from the transmitter. Next, in step S**220**, a determination is made whether the packet has been identified as a retransmitted type packet. If the packet has not been identified as a retransmittable type packet, control jumps to step S**230**.

In step S**230**, the packet is forwarded to a higher layer. Control then continues to step S**240** where the control sequence ends.

Alternatively, if the received packet is a retransmittable type packet, the packet is stored in the retransmission buffer in step S**260**. Next, in step S**270**, the integrity of the packet can be checked, for example utilizing a CRC. Then, in step S**280**, a determination is made whether the packet needs retransmission. If the packet needs retransmission, control continues to step S**290** where the retransmitted packet is obtained, for example, based on the sending of a message(s), one or the other transceiver determining a packet is missing, or the like, as discussed above, with control continuing back to step S**270** for an integrity check.

If the packet does not need retransmission, control continues to step S**295** where the packet is forwarded to a higher layer and deleted from the retransmission buffer. Control then continues to step S**240** where the control sequence ends.

FIG. **4** outlines an exemplary memory allocation method for sharing memory between the retransmission function and one or more of the interleaving/deinterleaving functionality and coding functionality. In particular, control begins in step S**300** and continues to step S**305**. In step S**305**, a message is sent/received specifying the available memory. Typically, the receiver will send a message to the transmitter specifying the available memory, but the transmitter could also send a message to the receiver. Next, in step S**310**, a determination is made as to how the memory should be allocated. As discussed, this allocation can be based on one or more of error correction capability, latency, buffering requirements, SNR, impulse noise, or in general, any communication parameter. Next, in step S**320**, the memory allocation is communicated to another transceiver. Then, in step S**330**, a determination can made as to whether the allocation is compatible. If the received allocation is not compatible, control continues to step S**360** wherein another allocation can be requested, with control continuing back to step S**320**.

Alternatively, if the allocation is compatible, in step S**340** the memory is allocated based on the received allocation. Control then continues to step S**350** where the control sequence ends.

FIG. **5** illustrates an exemplary memory sharing methodology for use with a retransmission function and one or more of interleaving/deinterleaving functionality, RS coding/decoding functionality. In particular, control begins in step S**400** and continues to step S**410**. In step S**410**, the memory allocation is received from, for example, a memory management module that may be located in the same transceiver, or at a remote transceiver. Next, in step S**420**, the memory sharing configuration is established and then, in step S**430**, the memory is shared between a retransmission function and one or more of the interleaving/deinterleaving functionality, RS coding/decoding functionality. Control then continues to step S**440**.

In step S**440**, a determination is made whether the memory sharing configuration should be changed. For example, the memory sharing configuration can be dynamically changed based on changes in the communication channel or data type(s) being sent on the communication channel. More specifically, for example, if the communications channel was not performing well, e.g., an increase in bit errors, it may be advantageous to increase the retransmission capability while decreasing the FEC/interleaving capability or vise-versa, which could have an impact on how the memory sharing should be configured.

If the memory sharing configuration should be changed, control continues to step S**450** where another allocation can be requested, with control continuing back to step S**410**. Otherwise, control continues to step S**460** where the control sequence ends.

While the above-described flowcharts have been discussed in relation to a particular sequence of events, it should be appreciated that changes to this sequence can occur without materially effecting the operation of the invention. Additionally, the exact sequence of events need not occur as set forth in the exemplary embodiments, but rather the steps can be performed by one or the other transceiver in the communication system provided both transceivers are aware of the technique being used for initialization. Additionally, the exemplary techniques illustrated herein are not limited to the specifically illustrated embodiments but can also be utilized with the other exemplary embodiments and each described feature is individually and separately claimable.

The above-described system can be implemented on wired and/or wireless telecommunications devices, such a modem, a multicarrier modem, a DSL modem, an ADSL modem, an xDSL modem, a VDSL modem, a linecard, test equipment, a multicarrier transceiver, a wired and/or wireless wide/local area network system, a satellite communication system, network-based communication systems, such as an IP, Ethernet or ATM system, a modem equipped with diagnostic capabilities, or the like, or on a separate programmed general purpose computer having a communications device or in conjunction with any of the following communications protocols: CDSL, ADSL2, ADSL2+, VDSL1, VDSL2, HDSL, DSL Lite, IDSL, RADSL, SDSL, UDSL or the like.

Additionally, the systems, methods and protocols of this invention can be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, a modem, a transmitter/receiver, any comparable means, or the like. In general, any device capable of implementing a state machine that is in turn capable of implementing the methodology illustrated herein can be used to implement the various communication methods, protocols and techniques according to this invention.

Furthermore, the disclosed methods may be readily implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed system may be implemented partially or fully in hardware using standard logic circuits or VLSI design. Whether software or hardware is used to implement the systems in accordance with this invention is dependent on the speed and/or efficiency requirements of the system, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The communication systems, methods and protocols illustrated herein can be readily implemented in hardware and/or software using any known or later

developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods may be readily implemented in software that can be stored on a storage medium, executed on programmed general-purpose computer with the cooperation of a controller and memory, a special purpose computer, a microprocessor, or the like. In these instances, the systems and methods of this invention can be implemented as program embedded on personal computer such as an applet, JAVA® or CGI script, as a resource residing on a server or computer workstation, as a routine embedded in a dedicated communication system or system component, or the like. The system can also be implemented by physically incorporating the system and/or method into a software and/or hardware system, such as the hardware and software systems of a communications transceiver.

It is therefore apparent that there has been provided, in accordance with the present invention, systems and methods for packet retransmission and memory sharing. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable arts. Accordingly, it is intended to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and scope of this invention.

The invention claimed is:

1. A method of packet retransmission comprising:

transmitting or receiving, using a transceiver, a plurality of packets;

identifying at least one packet of the plurality of packets as a packet that should be retransmitted;

allocating a memory between a retransmission function and an interleaving and/or deinterleaving function; and

transmitting or receiving a message during initialization, wherein the message indicates how the memory is to be allocated between the retransmission function and the interleaving and/or deinterleaving function, and wherein at least a portion of the memory may be allocated to the retransmission function or the interleaving and/or deinterleaving function at any one particular time.

2. The method of claim **1**, wherein the packets are used for video applications.

3. The method of claim **1**, wherein the packets are used for internet access applications.

4. The method of claim **1**, wherein the packets are used for voice applications.

5. The method of claim **1**, wherein the transceiver contains at least one ASIC.

6. The method of claim **1**, wherein the transceiver contains at least one DSP.

7. The transceiver of claim **1**, wherein the transceiver is located on a linecard that is transporting video, internet access and voice data.

8. The transceiver of claim **1**, wherein the transceiver is located in a customer premises equipment that is transporting video, internet access and voice data.

9. The transceiver of claim **1**, wherein a sum of a maximum amount of the memory that can be allocated to the retransmission function and a maximum amount of the memory that can be allocated to the interleaving and/or deinterleaving function is more than a total amount of the memory.

10. A transceiver capable of packet retransmission comprising:

a transmitter portion capable of: transmitting a plurality of packets, identifying at least one packet of the plurality of packets as a packet that should be retransmitted and allocating a memory between a retransmission function and an interleaving and/or deinterleaving function, wherein at least a portion of the memory may be allocated to the retransmission function or to the interleaving and/or deinterleaving function at any one particular time, and wherein a message transmitted during initialization indicates how the memory has been allocated between the retransmission function and the interleaving and/or deinterleaving function in the transceiver.

11. The transceiver of claim **10**, wherein the packets are used for video applications.

12. The transceiver of claim **10**, wherein the packets are used for internet access applications.

13. The transceiver of claim **10**, wherein the packets are used for voice applications.

14. The transceiver of claim **10**, wherein the transceiver contains at least one ASIC.

15. The transceiver of claim **10**, wherein the transceiver contains at least one DSP.

16. The transceiver of claim **10**, wherein the transceiver is located on a linecard that is capable of transporting video, internet access and voice data.

17. The transceiver of claim **10**, wherein a sum of a maximum amount of the memory that can be allocated to the retransmission function and a maximum amount of the memory that can be allocated to the interleaving/deinterleaving function is more than a total amount of the memory.

18. A transceiver capable of packet retransmission comprising:

a receiver portion capable of: receiving a plurality of packets, identifying at least one packet of the plurality of packets as a packet that should be retransmitted and allocating a memory between a retransmission function and an interleaving and/or deinterleaving function

wherein the memory is allocated between the interleaving function and the deinterleaving function in accordance with a message received during an initialization of the transceiver and wherein at least a portion of the memory may be allocated between the retransmission function and the interleaving and/or deinterleaving function at any one particular time depending on the message.

19. The transceiver apparatus of claim **18**, wherein the packets are used for video applications.

20. The transceiver of claim **18**, wherein the packets are used for internet access applications.

21. The transceiver of claim **18**, wherein the packets are used for voice applications.

22. The transceiver of claim **18**, wherein the transceiver contains at least one ASIC.

23. The transceiver of claim **18**, wherein the transceiver contains at least one DSP.

24. The transceiver of claim **18**, wherein the transceiver is located in a customer premises equipment that is capable of transporting video, internet access and voice data.

25. The transceiver of claim **18**, wherein a sum of a maximum amount of the memory that can be allocated to the retransmission function and a maximum amount of the memory that can be allocated to the interleaving and/or deinterleaving function is more than a total amount of the memory.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,468,411 B2
APPLICATION NO. : 12/783765
DATED : June 18, 2013
INVENTOR(S) : Marcos C. Tzannes

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In The Claims

Column 24, Claim 18, line 40, following "between" insert -- the retransmission function and --, therefore.

Column 24, Claim 18, line 41, delete "and" and insert -- and/or --, therefore.

Signed and Sealed this
Fifth Day of April, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

US009154354B2

(12) **United States Patent**
Tzannes

(10) **Patent No.: US 9,154,354 B2**
(45) **Date of Patent: Oct. 6, 2015**

(54) **SYSTEMS AND METHODS FOR A MULTICARRIER MODULATION SYSTEM WITH A VARIABLE MARGIN**

(71) Applicant: **TQ DELTA, LLC**, Austin, TX (US)

(72) Inventor: **Marcos C. Tzannes**, Alamo, CA (US)

(73) Assignee: **TQ DELTA, LLC**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Jan. 7, 2015**

(65) **Prior Publication Data**

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(Continued)

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H04B 1/38	(2015.01)

(52) **U.S. Cl.**

CPC ***H04L 27/2601*** (2013.01); ***H04B 1/38*** (2013.01); ***H04L 5/006*** (2013.01); ***H04L 5/0007*** (2013.01); ***H04L 5/0044*** (2013.01); ***H04L 5/0046*** (2013.01); ***H04L 27/2608*** (2013.01)

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CPC H04L 1/0002; H04L 1/1671; H04L 1/243; H04L 5/0007; H04L 5/0046; H04L 5/006; H04L 5/0044; H04L 5/14; H04L 27/2608; H04W 72/04; H04M 11/062

USPC 375/222, 227, 259–260, 285, 295, 316, 375/350; 370/484–485

See application file for complete search history.

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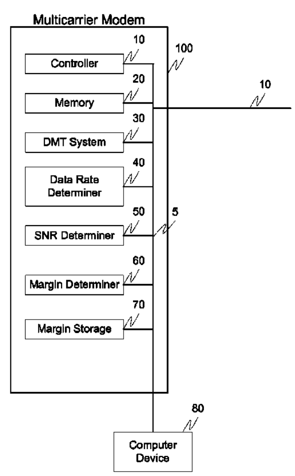
Primary Examiner — Khanh C Tran

(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross, PC

(57) **ABSTRACT**

A multicarrier modem has a plurality of carriers over which data is transmitted. By assigning, foe example, one or more different margins to the individual carriers the data rate and impairment immunity can be increased.

12 Claims, 2 Drawing Sheets



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continuation of application No. 12/694,143, filed on Jan. 26, 2010, now Pat. No. 8,374,226, which is a continuation of application No. 11/972,340, filed on Jan. 10, 2008, now abandoned, which is a continuation of application No. 11/242,024, filed on Oct. 4, 2005, now abandoned, which is a continuation of application No. 09/836,295, filed on Apr. 18, 2001, now abandoned.

(60) Provisional application No. 60/197,727, filed on Apr. 18, 2000.

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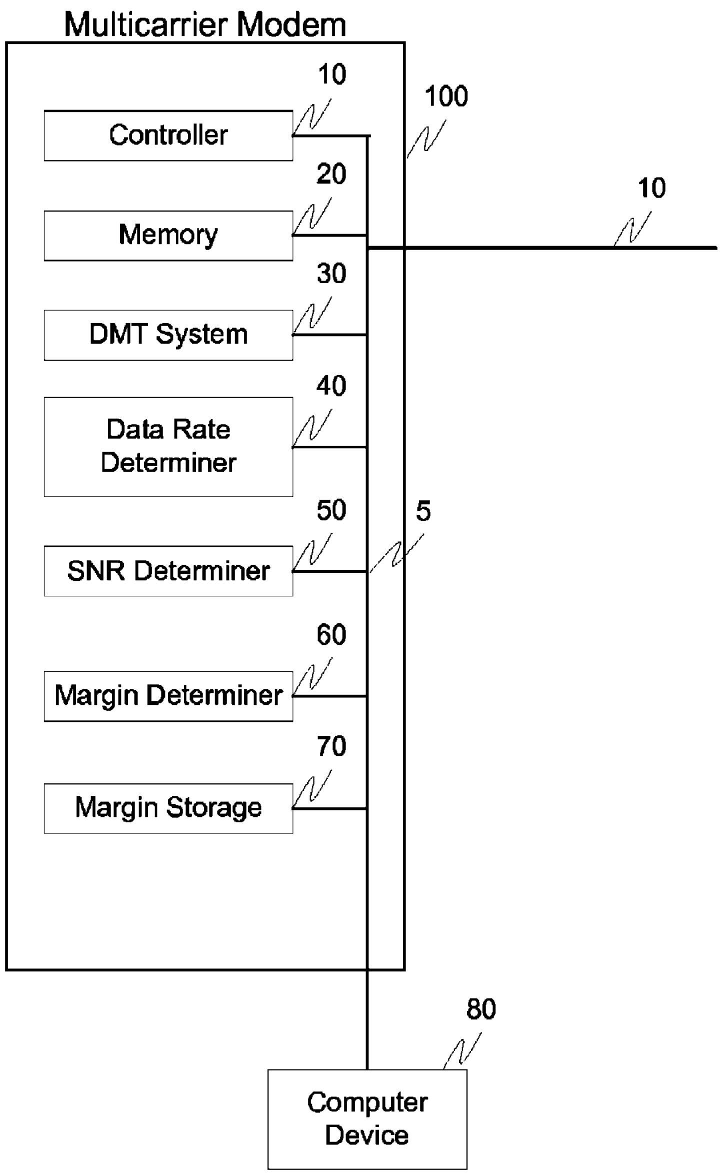
Multicarrier Modem
10
100
Controller
20
10
Memory
30
DMT System
40
Data Rate
Determiner
50
5
SNR Determiner
60
Margin Determiner
70
Margin Storage
80
Computer
Device

Fig. 1

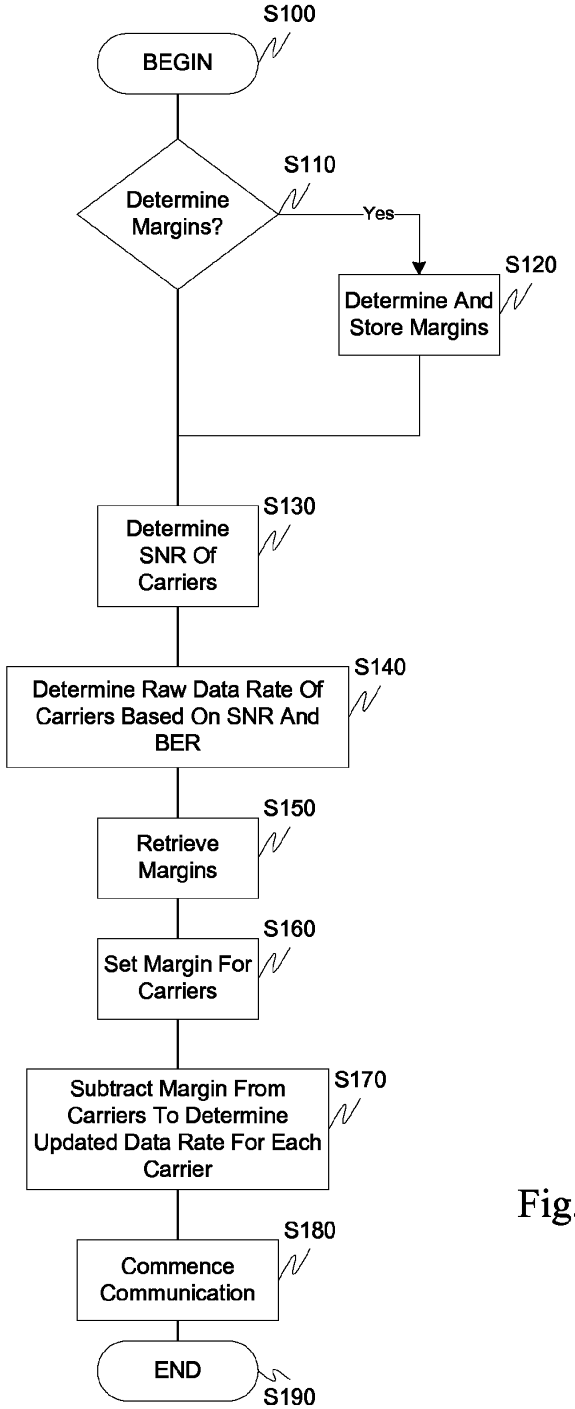
S100
BEGIN
S110
Determine Margins?
Yes
S120
Determine And Store Margins
S130
Determine SNR Of Carriers
S140
Determine Raw Data Rate Of Carriers Based On SNR And BER
S150
Retrieve Margins
S160
Set Margin For Carriers
S170
Subtract Margin From Carriers To Determine Updated Data Rate For Each Carrier
S180
Commence Communication
END
S190

Fig. 2

SYSTEMS AND METHODS FOR A MULTICARRIER MODULATION SYSTEM WITH A VARIABLE MARGIN

RELATED APPLICATION DATA

This application is a continuation of U.S. application Ser. No. 14/079,285, filed Nov. 13, 2013, now U.S. Pat. No. 8,937,988, which is a continuation of U.S. application Ser. No. 13/764,529, filed Feb. 11, 2013, now U.S. Pat. No. 8,625,660, which is a Continuation of U.S. application Ser. No. 12/694,143, filed Jan. 26, 2010, now U.S. Pat. No. 8,374,226, which is a continuation of U.S. application Ser. No. 11/972,340, filed Jan. 10, 2008, which is a continuation of U.S. application Ser. No. 11/242,024, filed Oct. 4, 2005, which is a continuation of U.S. application Ser. No. 09/836,295, filed Apr. 18, 2001, which claims the benefit of and priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 60/197,727, entitled "Multicarrier modulation system with variable margin to account for time varying impairments," filed Apr. 18, 2000, each of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to communications technologies. In particular, this invention relates to multicarrier modulation systems having multiple margins.

2. Description of Related Art

Multicarrier modulation, or Discrete Multitone Modulation (DMT), is a transmission method that is widely used for communication over difficult media. Multicarrier modulation divides the transmission frequency band into multiple subchannels, i.e., carriers or bins, with each carrier individually modulating a bit or a collection of bits. A transmitter modulates an input data stream containing information bits with one or more carriers, i.e., bins or subchannels, and transmits the modulated information. A receiver demodulates all the carriers in order to recover the transmitted information bits as an output data stream.

Multicarrier modulation has many advantages over single carrier modulation. These advantages include, for example, a higher immunity to impulse noise, a lower complexity equalization requirement in the presence of multipath, a higher immunity to narrow band interference, a higher data rate and bandwidth flexibility. Multicarrier modulation is being used in many applications to obtain these advantages, as well as for other reasons. These applications include Asymmetric Digital Subscriber Line (ADSL) systems, wireless LAN systems, power line communications systems, and other applications. ITU standards G.992.1 and G.992.2 and the ANSI T1.413 standard specify standard implementations for ADSL transceivers that use multicarrier modulation.

Discrete multitone modulation transceivers modulate a number of bits on each subchannel, the number of bits depending on the Signal to Noise Ratio (SNR) of that subchannel and the Bit Error Rate (BER) requirement of a link. For example, if the required BER is 1×10^{-7}, i.e., one bit in ten million is received in error on average, and the SNR of a particular subchannel is 21.5 dB, then that subchannel can modulate 4 bits, since 21.5 dB is the required SNR to transmit 4 QAM bits with a 1×10^{-7} BER. Other subchannels can have a different SNR and therefore may have a different number of bits allocated to them at the same BER. Additional information regarding bit loading can be found in copending U.S. application Ser. No. 09/510,773, incorporated herein by reference in its entirety.

In many DMT systems, an additional parameter is used to determine the number of bits allocated to each subchannel. This parameter is called the SNR "margin," or simply the "margin." The margin specifies an extra SNR per subchannel, in addition to what is required to maintain the specified BER requirement. As an example, a DMT system with a 6 dB margin would require a 21.5+6=27.5 dB SNR on a subchannel in order to transmit 4 bits on that subchannel with a 1×10^{-7} BER. This is 6 dB more than required by the example in the previous paragraph because now a 6 dB margin is added to the system. Another way of looking at this is that in the example of the previous paragraph, where 4 bits were allocated to a subchannel with 21.5 dB SNR, the margin was 0 dB.

DMT transceivers use a margin to increase the system's immunity to various types of time varying impairments. Examples of these impairments in DSL systems are: changes in the levels of crosstalk from other transmission systems, impulse noise, temperature changes in the telephone line, or the like. When a DMT system is operating with a positive SNR margin, the noise can change instantaneously by the level of the margin and the system will still maintain the required BER. For example, if the system is operating at a 6 dB margin, e.g., 4 bits are allocated to carriers with 27.5 dB SNR for BER=1×10^{-7}, the crosstalk levels can increase by 6 dB and the system will still be operating at the required 1×10^{-7} BER. Obviously the penalty for this increase in robustness is a decrease in the data rate, since with a 0 dB margin, a subchannel with 27.5 dB SNR can modulate 6 bits at 1×10^{-7} BER.

Therefore, there is a tradeoff between the robustness of the channel, such as a phone line, and the achievable data rate. The margin can be used to quantify this tradeoff. A higher margin results in a higher level of immunity to changing channel conditions at the expense of the achievable data rate. Likewise, a lower margin results in a higher data rate at the expense of a lower immunity to changing channel conditions.

Current DMT systems allocate a fixed margin to all subchannels. For example, ADSL systems typically use a 6 dB margin on all subchannels carrying data bits. This 6 dB margin is constant on all subchannels and is independent of the type of impairment that the margin is trying to protect against.

SUMMARY OF THE INVENTION

For simplicity of reference, the systems and methods of this invention will hereinafter refer to the transceivers, or multicarrier modems, generically as modems. One such modem is typically located at a customer premises such as a home or business and is "downstream" from a central office with which it communicates. The other modem is typically located at the central office and is "upstream" from the customer premises. Consistent with industry practice, the modems are often referred to as "ATU-R" ("ADSL transceiver unit, remote," i.e., located at the customer premises) and "ATU-C" ("ADSL transceiver unit, central office," i.e., located at the central office). Each modem includes a transmitter section for transmitting data and a receiver section for receiving data, and is of the discrete multitone type, i.e., the modem transmits data over a multiplicity of subchannels of limited bandwidth. Typically, the upstream or ATU-C modem transmits data to the downstream or ATU-R modem over a first set of subchannels, which are usually the higher-frequency subchannels, and receives data from the downstream

or ATU-R modem over a second, usually smaller, set of subchannels, commonly the lower-frequency subchannels.

For example, in digital subscriber line (DSL) technology, communications over a local subscriber loop between a central office and a subscriber premises is accomplished by modulating the data to be transmitted onto a multiplicity of discrete frequency carriers which are summed together and then transmitted over a subscriber loop. Individually, the carriers form discrete, non-overlapping communication subchannels which are of a limited bandwidth. Collectively, the carriers form what is effectively a broadband communications channel. At the receiver end, the carriers are demodulated and the data recovered.

DSL systems experience disturbances from other data services on adjacent phone lines, such as, for example, ADSL, HDSL, ISDN, T1, or the like. Additionally, DSL systems may experience disturbances from impulse noise, crosstalk, temperature changes, or the like. These disturbances may commence after the subject DSL service is already initiated and, since DSL for Internet access in envisioned as a always-on service, the affects of these disturbances should be considered by the subject DSL transceiver. Additionally, the length of the phone line is a type of impairment that varies from one ADSL subscriber to another, i.e. from one ADSL installation to another, and therefore has an effect on the ADSL modem performance.

The systems and methods of this invention allow the margin in a discrete multitone modulation system to vary depending on a type of impairment. For example, this impairment can be changing over some duration or from one installation to another. Thus, different margins can be assigned to one or more of the carriers in a discrete multitone modulation communication system.

As noted above, there is a tradeoff between the robustness of the link and the achievable data rate. By setting a higher margin, a higher level of immunity to changing channel conditions is achieved at the expense of the data rate. Similarly, while a lower margin may result in a higher data rate, the immunity to changing channel conditions is reduced.

However, setting the margin equally for all subchannels at least fails to account for impairments that change over time and how the impairments may have different effects on subchannels at different frequencies. For example, temperature changes and line length effect different frequencies with differing degrees of interference.

Aspects of the present invention relate to a communications system having a plurality of margins.

Aspects of the present invention also relates to a method of assigning a plurality of margins to a communications system.

Aspects of this present invention additionally relate to multicarrier modulation systems and methods for different margins to be assigned to different subchannels to account for varying impairments.

These and other features and advantages of this invention are described in, or are apparent from, the following detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the invention will be described in detail, with reference to the following figures wherein:

FIG. **1** is a functional block diagram illustrating an exemplary modem according to this invention; and

FIG. **2** is a flowchart outlining an exemplary method for assigning margins according to this invention.

DETAILED DESCRIPTION OF THE INVENTION

In an exemplary embodiment of the invention, the margin is set to be different on at least two subchannels in a discrete multitone modulation system. In this exemplary embodiment, subchannels which are expected to incur greater variations in impairment levels are set to have a higher margin, whereas subchannels which are expected to incur lower variations in impairment levels are set to have lower margins. As an example of this embodiment, consider an ADSL transmission system transmitting data over telephone wires and consider the case where the impairment is changing channel conditions due to temperature fluctuations. Since telephone wire is typically made out of copper, the attenuation, i.e., the insertion loss, characteristics will depend on the temperature of the wire. As the temperature of the wire increases, the attenuation, i.e., the insertion loss, will increase. Furthermore, the insertion loss also varies with frequency as the temperature changes. Therefore, as the temperature increases, in addition to an overall increase in insertion loss, the insertion loss at the higher frequencies increases more than the insertion loss at the lower frequencies. Table 1 shows a correlation of frequency versus insertion loss of an exemplary 13,500 ft. 26 AWG line at various frequencies for 70° F. and 120° F.

TABLE 1

Insertion loss of 13500 ft 26 AWG line versus frequency at 70 F. and 120 F.

	Frequency (kHz)										
	20	40	100	200	260	300	400	500	600	780	1100
Insertion loss (dB) at 70° F.	29.8	36.7	45.2	52.8	57.3	60.2	67.7	74.8	81.7	93.0	110
Insertion loss (dB) at 120° F.	31.9	39.6	49.4	57.4	61.8	64.8	72.3	79.3	86.1	97.9	116

From Table 1, it is apparent that the difference in insertion loss from 120° F. to 70° F. is 2.1 dB at 20 kHz, whereas the difference in insertion loss from 120° F. to 70° F. is 6 dB at 1100 kHz. For this exemplary embodiment, a higher margin could be allocated to carriers at higher frequencies and a lower margin allocated to carriers at lower frequencies. For example, the carrier at 20 kHz will only need a 2.1 dB margin, because even if the temperature changes from 70° F. to 120° F., the insertion loss will only change by 2.1 dB and, as a result, the system bit error rate requirement can still be met after the temperature change. Similarly, the carrier at 1100 kHz will need a 6 dB margin, since as the temperature changes from 70° F. to 120° F., the insertion loss will change by 6 dB and, as a result, the system bit error rate requirement will still be satisfied even after the temperature change.

However, it is to be appreciated that the margin is not allocated to each subchannel in a fixed manner, but rather varies based on the expected change in impairments over time

or as impairments vary from one DSL installation to another. However, that does not preclude the possibility that different subchannels can have the same margin assigned to them. For example, a subchannel may have a certain margin assigned based on a particular impairment, while another subchannel may have the same margin assigned based on another impairment. These impairments can include, but are not limited to, changes in the levels of crosstalk from other transmission systems, impulse noise, temperature changes, line length, radio frequency interference and other ingress, or the like. As a result, for example, since certain subchannels are not overly burdened with a common margin, the overall data rate of the system can be increased without sacrificing the robustness of the system.

For example, and with reference to Table 1, by lowering the margin of the lower carriers from 6 dB to 2.1 dB, the channel data rate has increased. This increase can occur without a loss of the immunity to temperature variations on the line since the lower frequencies are less susceptible to temperature changes than the higher frequencies. In general, the systems and methods of this invention can be adapted to set a margin for any impairment that varies over time, or is installation based, and may, for example, effect different frequencies in different ways.

As another example, consider crosstalk from another transmission system. If the crosstalking transmission system is known to use only a portion of the frequency spectrum utilized by the discrete multitone modulation system, then the margins can be decreased on the carriers that are known to be outside the frequency spectrum of the crosstalking system. For example, ISDN systems are an example of a crosstalk source for ADSL systems. ISDN systems typically transmit only up to approximately 150 kHz. Thus, for example, employing the teachings of this invention, carriers above 150 kHz can operate at lower margins than carriers below 150 kHz where the ISDN crosstalk is present.

As another example, the margin in an ADSL system can be varied depending on the length of the telephone wire. Table 2 shows a relationship of insertion loss of an exemplary 9000 ft. 26 AWG line at frequencies for 70° F. and 120° F.

TABLE 2

Insertion loss of 9000 ft 26 AWG line versus frequency at 70 F. and 120 F. Frequency (kHz)											
	20	40	100	200	260	300	400	500	600	780	1100
Insertion loss (dB) at 70° F.	20.0	24.4	30.1	35.2	38.2	40.2	45.1	49.9	54.4	62.0	73.6
Insertion loss (dB) at 120° F.	21.4	26.3	32.8	38.2	41.2	43.2	48.2	52.9	57.4	65.3	77.5

Comparing Table 1 and Table 2, it is apparent that an increase in insertion loss as temperature increases depends on the length of the telephone line as well. Thus, on the exemplary 9,000 ft. phone line, a 50° F. temperature change results in an average of only 2.8 dB increase in insertion loss. On the 13,500 ft. phone line, a 50° F. temperature change resulted in an average of 4.3 dB increase in insertion loss. For this illustrative example, the margin on the subchannels is varied depending on the length of the phone line. As an example, if the phone line is shorter, e.g., 9,000 ft., the average margin can be decreased on the subchannels by 4.3−2.8=1.5 dB as compared to a longer 13,500 ft. loop without sacrificing immunity to temperature changes on the phone line. This is possible because a shorter phone line will not experience as much of a change in insertion loss due to temperature changes as a longer phone line.

For this illustrative example, the margin allocated to different subchannels takes into account information about the length of the telephone line. As an example, the insertion loss difference from 70° F. to 120° F. at 20 kHz is 2.1 dB for the 13,500 ft. line. On the other hand, the insertion loss difference from 70° F. to 120° F. at 20 kHz is 1.4 dB for the 9,000 ft. line. Therefore, for this exemplary situation, a margin of 2.1 dB would be allocated to the carrier at 20 kHz on a 13,500 ft. line whereas a margin of 1.4 dB would be allocated to the carrier at 20 kHz on the 9,000 ft. line. The immunity to temperature variations on the line would be the same for both the systems operating at 9,000 ft. and 13,500 ft. As a result, the overall system data rate can be increased on shorter lines without sacrificing a loss in robustness.

FIG. **1** illustrates an exemplary embodiment of a multicarrier modem **100**. In particular, the multicarrier modem **100** comprises a controller **10**, a memory **20**, a discrete multitone modulation system **30**, a data rate determiner **40**, a signal to noise ratio determiner **50**, a margin determiner **60** and a margin storage **70**, all interconnected by link **5**. The multicarrier modem **100** is also connected to one or more computer or computer-type devices **80** and additional modems (not shown) via communications link **10**. For ease of illustration, the multicarrier modem **100** has been illustrated in block diagram format with only the components needed for the exemplary embodiment of this invention. Additional information and further discussion of the operation and structure of an exemplary multicarrier modem can be found in copending U.S. patent application Ser. No. 09/485,614 entitled "Splitterless Multicarrier Modem."

While the exemplary embodiment illustrated in FIG. **1** shows the multicarrier modem **100** and various components collocated, it is to be appreciated that the various components of the multicarrier modem can be rearranged and located in whole or in part at an ATU-R and/or ATU-C. Furthermore, it is to be appreciated, that the components of the multicarrier modem **100** can be located at various locations within a distributed network, such as a POTS network, or other comparable telecommunications network. Thus, it should be appreciated, that the components of the multicarrier modem **100** can be combined into one device or distributed amongst a plurality of devices. As will be appreciated from the following description, and for reasons of computational efficiency, the components of the multicarrier modem can be arranged at any location within a telecommunications network and/or modem without affecting the operation of the system.

The links **5** and **10** can be a wired or a wireless link or any other known or later developed element(s) that is capable of supplying and communicating electronic data to and from the connected elements. Additionally, the computer device **80**,

can be, for example, a personal computer or other device. In general, the computer device **80** can be any device that uses a modem to transmit and/or receive data.

In operation, the multicarrier modem **100** is installed, for example, in a customer premises or in a central office. During this installation, certain fixed quantities such as line length are known and can be stored in the multicarrier modem **100**. During an initial installation, or at any subsequent time for which a redetermination in margins is appropriate, for example, based on an increased bit error rate, changes in the signal to noise ratio, seasonal changes, or the like, the controller **10**, in cooperation with the memory **20**, the discrete multitone modulation system **30** and the margin determiner **60** can determine and store margins. For example, as illustrated above in exemplary Tables 1 and 2, margins can be determined for temperature fluctuations and the length of the wire line based on, for example, the actual installation and historical data. Furthermore, routines can be established by the margin determiner **60** to evaluate and compile statistical information relating to one or more carriers. For example, this statistical information can be compiled during modem idle times in response to impairments seen on the one or more carriers. This statistical information can then be used to determine appropriate margins for one or more carriers.

Alternatively the modem may measure the noise on the line during idle times and determine that a particular type of crosstalker, e.g., another ADSL or HDSL modem, is present. Since the spectral content of these types of crosstalkers are known, this information can be used to determine the margin. For example, if the crosstalker is an ATU-R ADSL modem then it is known that ATU-R ADSL modems transmit approximately in the 20-130 kHz range. This information can be used to determine the margin for the carriers in the 20-130 kHz frequency range.

Alternatively, a predetermined set of margins, for example, for known impairments, can be downloaded from, for example, a central office modem or other location within a communications network. The determined and/or downloaded margins are then stored in the margin storage **70**. Similarly, groups of margins can be stored based on, for example, geographic information, seasonal information, line length information, or the like.

During training of the multicarrier modem **100**, the SNR determiner **50**, in cooperation with the controller **10**, the memory **20**, and the DMT system **30**, determines the signal to noise ratio of the carriers. Knowing the signal to noise ratio of the carriers, the data rate determiner **40** determines the raw data rate of the carriers based on the signal to noise ratio and the bit error rate. This raw data rate reflects the data rate of carriers with no margin.

Generally, the bit error rate is set in advance, for example, by the manufacturer. Additionally, the data rate is generally governed by a range that is, for example, guaranteed as a maximum, by a DSL provider. Therefore, based on the set bit error rate, the signal to noise ratio for a known quantity of bits can be determined.

Knowing the signal to noise ratio, the margins for the carriers can be set, for example, based on one or more, or a combination of, entered criteria or determined criteria. For example, an entered criteria can be based on the loop length. A determined criteria can be, for example, based on standard temperature variance information that can, for example, be downloaded from the service provider. Alternatively, for example, the margins can be set based on historical data that relates to, for example, impairments on the line. In general, the margins can be set such that a balance between the data rate and the impairment immunity is maximized.

Having retrieved the margins for one or more of the carriers, the margins are set in the DMT system **30**. The margins can then be subtracted from the carrier to determine an updated data rate for each carrier. Having set the margins, and knowing the data rate, the DMT system can then commence communication over the communications link **10**.

FIG. **2** illustrates an exemplary method of assigning margins to carriers according to an exemplary embodiment of this invention. In particular, control begins in step S**100** and continues to step S**110**. In step S**110**, a determination is made whether margins are to be determined. If margins are to be determined, control continues to step S**120**. Otherwise, control jumps to step S**130**.

In step S**120**, the margins are determined and stored. Control then continues to step S**130**.

In step S**130** the signal to noise ratio of the carriers are determined. Next, in step S**140**, the raw data rate of the carriers is determined based on the signal to noise ratio and the bit error rate. Next, in step S**150**, the margins for the carriers are retrieved. Control then continues to step S**160**.

In step S**160**, the margins for the carriers are set. Next, in step S**170**, the margins are subtracted from the carriers to determine an updated data rate for each carrier. Control then continues to step S**180**.

In step S**180**, communications commence. Control then continues to step S**190** where the control sequence ends.

However, it is to be appreciated that the steps in FIG. **2** need not occur in the order illustrated. For example, at any point in time there could be an option to re-determine the margins. Similarly, based on, for example, the time of the day, day, location, error rate, service provider directive, a change in the quality of service requirement, or the like, the margins could be adjusted. Alternatively, at any time, updated margins could be downloaded and stored in the margin storage. Alternatively, if it known that margins will be incorporated in the determination of the data rate, step S**140** could be bypassed since it is known that the raw data rate will not be used.

Furthermore, the systems and methods of this invention can also apply to any multicarrier modulation based communication system including wireless LANs, such as wireless LAN 802.11 and ETSI Hyperlan standards, wireless access systems, home and access power-line communication systems, or the like.

As illustrated in FIG. **1**, the multicarrier modem and related components can be implemented either on a DSL modem, or a separate program general purpose computer having a communications device. However, the multicarrier modem can also be implemented in a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element, and ASIC or other integrated circuit, a digital signal processor, a hardwired or electronic or logic circuit such as a discrete element circuit, a programmable logic device such as a PLD, PLA, FPGA, PAL, or the like, and associated communications equipment. In general, any device capable of implementing a finite state machine that is in turn capable of implementing the flowchart illustrated in FIG. **2** can be used to implement the multicarrier modem **100** according to this invention.

Furthermore, a disclosed method may be readily implemented in software using object or object-oriented software development environment that provides portable source code that can be used on a variety of computers, workstations, or modem hardware platforms. Alternatively, the disclosed modem may be implemented partially or fully in hardware using standard logic circuits or a VLSI design. Other software or hardware can be used to implement the systems in accordance with this invention depending on the speed and/or

efficiency requirements of the systems, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The multicarrier modem illustrated herein, however, can be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods can be readily implemented as software executed on a programmed general purpose computer, a special purpose computer, a microprocessor and associated communications equipment, or the like. In these instances, the methods and systems of this invention can be implemented as a program embedded on a modem, such as a DSL modem, or the like. The multicarrier modem can also be implemented by physically incorporating the system and method in a software and/or hardware system, such as a hardware and software system of a modem, such as an ADSL modem, or the like.

It is, therefore, apparent that there has been provided in accordance with the present invention, systems and methods for assigning margins to carriers. While this invention has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be or are apparent to those of ordinary skill in the applicable art. Accordingly, Applicants intend to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and the scope of this invention.

What is claimed is:

1. A method in a multicarrier communications transceiver comprising:

transmitting a multicarrier symbol comprising a first plurality of carriers and a second plurality of carriers;

transmitting a first plurality of bits on the first plurality of carriers using a first SNR margin;

transmitting a second plurality of bits on the second plurality of carriers using a second SNR margin;

wherein the first plurality of carriers is different than the second plurality of carriers,

wherein the first SNR margin is different than the second SNR margin, and

wherein the first SNR margin provides more robust transmission than the second SNR margin.

2. The method of claim **1**, wherein the first SNR margin specifies a first value for an increase in noise associated with the first plurality of carriers.

3. The method of claim **1**, wherein the second SNR margin specifies a second value for an increase in noise associated with the second plurality of carriers.

4. A method in a multicarrier communications transceiver comprising:

receiving a multicarrier symbol comprising a first plurality of carriers and a second plurality of carriers;

receiving a first plurality of bits on the first plurality of carriers using a first SNR margin;

receiving a second plurality of bits on the second plurality of carriers using a second SNR margin;

wherein the first plurality of carriers is different than the second plurality of carriers,

wherein the first SNR margin is different than the second SNR margin, and

wherein the first SNR margin provides more robust reception than the second SNR margin.

5. The method of claim **4**, wherein the first SNR margin specifies a first value for an increase in noise associated with the first plurality of carriers.

6. The method of claim **4**, wherein the second SNR margin specifies a second value for an increase in noise associated with the second plurality of carriers.

7. A multicarrier communications transceiver operable to:

transmit a multicarrier symbol comprising a first plurality of carriers and a second plurality of carriers;

transmit a first plurality of bits on the first plurality of carriers using a first SNR margin;

transmit a second plurality of bits on the second plurality of carriers using a second SNR margin;

wherein the first plurality of carriers is different than the second plurality of carriers,

wherein the first SNR margin is different than the second SNR margin, and

wherein the first SNR margin provides more robust transmission than the second SNR margin.

8. The transceiver of claim **7**, wherein the first SNR margin specifies a first value for an increase in noise associated with the first plurality of carriers.

9. The transceiver of claim **7**, wherein the second SNR margin specifies a second value for an increase in noise associated with the second plurality of carriers.

10. A multicarrier communications transceiver operable to:

receive a multicarrier symbol comprising a first plurality of carriers and a second plurality of carriers;

receive a first plurality of bits on the first plurality of carriers using a first SNR margin;

receive a second plurality of bits on the second plurality of carriers using a second SNR margin;

wherein the first plurality of carriers is different than the second plurality of carriers,

wherein the first SNR margin is different than the second SNR margin, and

wherein the first SNR margin provides more robust.

11. The transceiver of claim **10**, wherein the first SNR margin specifies a first value for an increase in noise associated with the first plurality of carriers.

12. The transceiver of claim **10**, wherein the second SNR margin specifies a second value for an increase in noise associated with the second plurality of carriers.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,154,354 B2
APPLICATION NO. : 14/591612
DATED : October 6, 2015
INVENTOR(S) : Tzannes

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

• At Column 10, Line 47, Claim 10, immediately following “robust” delete “transmission” and insert -- reception --, therefore.

This certificate supersedes the Certificate of Correction issued October 30, 2018.

Signed and Sealed this
Fifteenth Day of June, 2021

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

CERTIFICATE OF CONFIDENTIAL MATERIAL

Case Number: 24-1587, 24-1588

Short Case Caption: TQ Delta, LLC v. CommScope Holding Company, Inc.

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Date: 07/19/2024

Signature: /s/ Jeffrey A. Lamken

Name: Jeffrey A. Lamken

UNITED STATES COURT OF APPEALS
FOR THE FEDERAL CIRCUIT

CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATIONS

Case Number: 24-1587, 24-1588

Short Case Caption: TQ Delta, LLC v. CommScope Holding Company, Inc.

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Date: 07/19/2024

Signature: /s/ Jeffrey A. Lamken

Name: Jeffrey A. Lamken